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A study of light attenuation in Monterey Bay, California.

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A STUDY OF LIGHT ATTENUATION IN MONTEREY BAY, CALIFORNIA

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THESIS

A Study of Light Attenuation

in Monterey Bay, California

by

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A Study of Light Attenuation in Monterey Bay, California

by

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ABSTRACT

A single ocean station was occupied for 27 hours during the Upwelling Period in Monterey Bay, California, to study light attenuation and its relation to other standard oceanographic parameters. Comparisons were made with earlier local studies.

It was found that the vertical distributions of the oceanographic parameters studied are dependent on both the seasonal conditions and geographical location.

The largest concentration of suspended particles was found in the upper 10-15 m of the water column where most of the light attenuation occurred. The largest attenuation gradient was found in the pycnocline. A linear relation was suggested between the attenuation coefficient and the cumulative projected cross-sectional area of the particles.

Apparent relations were found between light attenuation and temperature, salinity, density, and oxygen and phosphate concentrations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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I. INTRODUCTION

A. BACKGROUND

1. Optical Properties of Sea Water

Current interest in underwater laser systems, undersea habitation, and the use of deep submergence vehicles and underwater television and photographic camera systems requires detailed knowledge of the propagation of visible light in the ocean at various wavelengths, in a variety of locations, and at great depths, as well as information on how this propagation varies with time [15].

There are two types of optical properties of sea water, the apparent and the inherent. The apparent properties depend on the light field as well as on the physical composition of the water. Inherent optical properties are the result of the physical action of the medium on a given beam of light, independent of beam orientation and existing light conditions [25]. Inherent optical properties include transmissivity, volume attenuation, volume scattering, and absorption functions, while the apparent properties include radiance and irradiance. It is with an inherent property that this study concerns itself.

Beam transmissivity per meter is the ratio of light energy received over a one meter path, I_r, to that entering the beam, I_o:

$$T = I_r/I_o \quad .$$

The volume attenuation coefficient is the negative natural logarithm of the transmissivity, and can be represented as follows:

$$I_r = I_o e^{-\alpha(\lambda)d}$$

where

$\alpha(\lambda)$ = attenuation coefficient

d = distance between source and receiver.

The attenuation coefficient $\alpha(\lambda)$, which is a function of wavelength λ, may be considered to be the sum of a volume absorption coefficient $a(\lambda)$ and a volume scattering function $s(\lambda)$, such that

$$\alpha(\lambda) = a(\lambda) + s(\lambda).$$

Absorption includes all of the many thermodynamically irreversible processes by which photons are changed in their nature. Transformation of photon energy into thermal kinetic energy or chemical potential energy is the major absorption mechanism in the ocean [7].

Scattering, on the other hand, refers to any random process by which the direction of individual photons is changed without any other alternation. Scattering of light in the sea is predominantly due to transparent biological organisms and particles that are large when compared with the wavelength of light [7].

2. Factors Affecting Light Attenuation

The attenuation coefficient $\alpha(\lambda)$ is a function of the wavelength of light. This variation with wavelength is due almost wholly to selective absorption. Sea water possesses only a single important transmission "window", the peak of which lies near 480 mμ. This peak is shifted progressively toward the green as the quantity of dissolved organic matter increases [7]. The term Gelbstoff or "yellow substance" has been used to describe such dissolved organic compounds which tend to be yellow colored. In the open ocean Gelbstoff results in part from the chemical degradation products of plankton. It is not an exactly defined chemical compound, but rather is a complex mixture of compounds. In river waters it comes mainly from humus [13].

In pure water containing no suspended particles or in which the scattering centers have dimensions very small with respect to the wavelength of light the scattering coefficient varies inversely with the fourth power of the wavelengh (Rayleigh scattering). In most ocean water, on the other hand, where particles occur that are large compared to the wavelength, the scattering coefficient is almost independent of wavelength [7].

While the distribution of particles suspended in the ocean is intimately related to the production of living matter, these particles can be divided into organic and inorganic suspensions. Application of theory to observed data indicates that a large share of the particles that cause light attenuation are less than two microns in diameter, and that these particles occur in concentrations from less than one to approximately 60 ppm by volume [5]. Ochakovsky [16] has observed that the maximum percentage of organic suspensions have diameters from 10 to 25 μ, and inorganic suspensions have diameters from 1 to 2.5 μ. The value of the attenuation factor depends upon the concentration of the smaller particles much more so than it does on the larger ones. Scattering produced by suspended particles is dependent on their concentration and index of refraction as well as on their size. The characteristic curve of extinction against wavelength of light for the visible part of the spectrum may be interpreted in terms of the Mie theory [5]. While it can be concluded that suspended particles do indeed play an important part in the scattering of light in sea water, Burt [4] found that matter which could be filtered out of Chesapeake Bay waters, was at least four times as effective in scattering at all wavelengths as the matter that could not be filtered out. The filter-passing material consisted of fine suspensions and whatever dissolved matter that was present.

Seasonal conditions also have a decided affect on light attenuation in the ocean. There are three principal seasons that occur along the Central California Coast. The Upwelling Period, from January to September, is characterized by lower than normal surface temperatures (10-11 °C) with no clearly developed isotherms present. This is the most pronounced season, and upwelling is most intense in June and July. The Oceanic Period, from September to November, is characterized by surface temperatures averaging more than 13 °C. This is the warmest time of the year, and there is a sharp thermocline at a depth of only a few meters. The Davidson Current Period, from November to January, is characterized by surface waters that are only slightly cooler than during the Oceanic Period. The thermocline weakens markedly as it is depressed to depths of between 50 and 100 m [3].

Upwelling is an ascending motion of some minimum extent by which water from sub-surface layers is brought into the surface layer and is removed from the area by horizontal flow. Upwelling off the west coast of the United States is a direct effect of the coastal winds. The North Pacific High dominates the atmospheric circulation during the spring and summer months. The predominating winds are northerly or northwesterly, blowing equatorward parallel to the coast. The surface waters are driven offshore by Ekman transport, resulting in upwelling as the water is replaced from deeper layers. Upwelling causes shallow isotherms to ascend steeply, sometimes intersecting the surface. The vertical temperature gradient may decrease inshore, while there is a relatively large horizontal temperature gradient in the surface waters. The usual affect of upwelling is to decrease surface salinity, but along the California coast the surface salinity is increased. While density structure follows the temperature structure, off the California coast the

combined effect of the thermocline and halocline gives a very strong pycnocline which may intersect the surface as a front during intense upwelling. Surface waters become markedly undersaturated in oxygen, while high values of phosphate occur in upwelling regions where subsurface waters come to the surface [22].

3. Uses of Beam Transmittance Data

The spectral dependence of the beam attenuation coefficient (alpha) on the nature of scattering and absorpting constituents of the water makes it a useful means of characterizing and identifying water masses [7]. In addition to being a sensitive measure of the location and movement of water in the study of ocean and tidal currents, alpha provides important information for the study of ocean ecology [18].

Studies of light attenuation have resulted in some interesting findings (see Jerlov [10]). It has been found that the increase in concentration of particulate matter as the bottom is approached is affected by horizontal flow. Such flow, caused chiefly by tides, results in the rising and sinking of sediment in accord with the tidal rhythm. The horizontal distribution of the attenuation coefficient has to some extent provided a basis for a new approach to study of horizontal diffusion in the sea. Success has accompanied efforts to use beam transmittance as a property for identifying water masses, areas of upwelling, and current structure. In addition, movements of a discontinuity layer that is indicated by the collecting of particles, can be followed. Jerlov [9] has also found that the abundance of "yellow substance" found in some rivers makes it possible to localize from its distribution the fresh-water tongues near such river mouths.

B. PREVIOUS LOCAL STUDIES

A continuing series of oceanographic surveys has been conducted by the Naval Postgraduate School off the Central California Coast. The following studies are reviewed with emphasis on their conclusions as they pertain to the transmissivity of sea water. All of the studies were concerned with only the upper 100 m of surface water.

1. Yeske and Waer [26]

L.A. Yeske and R.D. Waer conducted the first in a series of investigations during the Upwelling Period. Two stations within Monterey Bay, California, were occupied during July and August 1968. From their study they found that isolated pockets of relatively high or low salinity appeared to be associated with beam transmittance perturbations. In spite of this, a salinity relation with beam transmittance was not clearly defined. There was fair relation between beam transmittance contours and temperature isolines and isopycnals. There was some relation with particulate matter. The regions of greatest particulate concentrations were in the pycnocline and thermocline, where the greatest change in transmissivity was observed. There seemed to be roughly a linear relationship between values of particle count and beam transmittance.

2. Labyak [14]

P.S. Labyak also conducted his studies during the Upwelling Period from 10-18 May 1969. He investigated 79 oceanographic stations along the Pacific Coast between San Francisco Bay and Monterey Bay and found a fairly good relation between beam transmittance and temperature except in the near shore areas. As did Yeske and Waer, Labyak found that beam transmittance and particulate matter concentrations related fairly well.

3. Shepard [20]

A.B. Shepard also conducted a study during the Upwelling Period. He investigated 85 stations between Monterey Bay and San Francisco Bay during the period 29 April - 5 May 1970. A fair relationship was found to exist between beam transmission and particle count. In addition, he found that the surface layers containing high oxygen, high chlorophyll a, and low nutrients, all indicating high productivity, were associated with high particle count and low transmissivity.

4. Baker [2]

The first of these studies during the Oceanic Period was by R.S. Baker. He occupied 86 stations between Monterey Bay and San Francisco Bay from 7-14 November 1969. Other than observing a layer of maximum particle count within the thermocline, no relation between temperature and beam transmittance was observed. As with the other investigators, Baker found good relation between particle count and beam transmittance. No relation between beam transmittance and oxygen content was observed.

5. Soluri [23]

E.S. Soluri also investigated the area during the Oceanic Period from 1-6 November 1970. This study included the investigation of 86 stations along the coast between San Francisco Bay and Monterey Bay. In contrast to all previous studies, he found a poor over-all relation between cummulative particle volume and beam attenuation coefficient.

C. OBJECTIVE

In the analysis of oceanographic data one must find qualitative relationships between various parameters before quantitative correlation analysis is performed.

The objective of the present study was to find the qualitative relations between alpha and temperature, salinity, density, oxygen and phosphate concentrations, and particulate matter at a single ocean station occupied for an extended period of time, and to make comparisons with previous local studies.

II. OBSERVATIONAL PROCEDURE

A. CRUISE PROCEDURE

For a 27 hour period beginning at 0600 on 16 June 1971 a single oceanographic station was occupied in Monterey Bay (36° 41.8' N, 122° 02.8' W) over the Monterey Submarine Canyon in approximately 900 fathoms of water (Figure 1). This location approximates open-water conditions and was occupied by Bolin at weekly intervals from 1951-55 [3]. The USNS BARTLETT (T-AGOR-13) was the oceanographic vessel used. Prior to each observation, the ship was repositioned using radar and visual sightings. It is estimated that the positioning error was of the order of ± 460 m.

B. INSTRUMENTATION

A Marine Advisors' Model C-2 Beam Transmissometer (alpha meter) was used. This instrument is described in detail by Yeske and Waer [26]. Prior to this investigation, the alpha meter was over-hauled by Marine Advisors, Inc., San Diego, California, to reduce the beam diameter to a size somewhat smaller than the receiver entrance pupil, and the instrument was pressure tested to 1000 feet. In addition, it was compared with a Scripps folded path transmissometer [19] at the Visibility Laboratory, Scripps Institute of Oceanography, San Diego, California. The two instruments were found to agree favorably over a wide range of transmissivity.

In order to allow its use below the previous 100 meter-limit, the alpha meter was used with a 6-volt lead-acid battery pack and a winch fitted with 3/16" 4-conductor armored cable. The battery provided

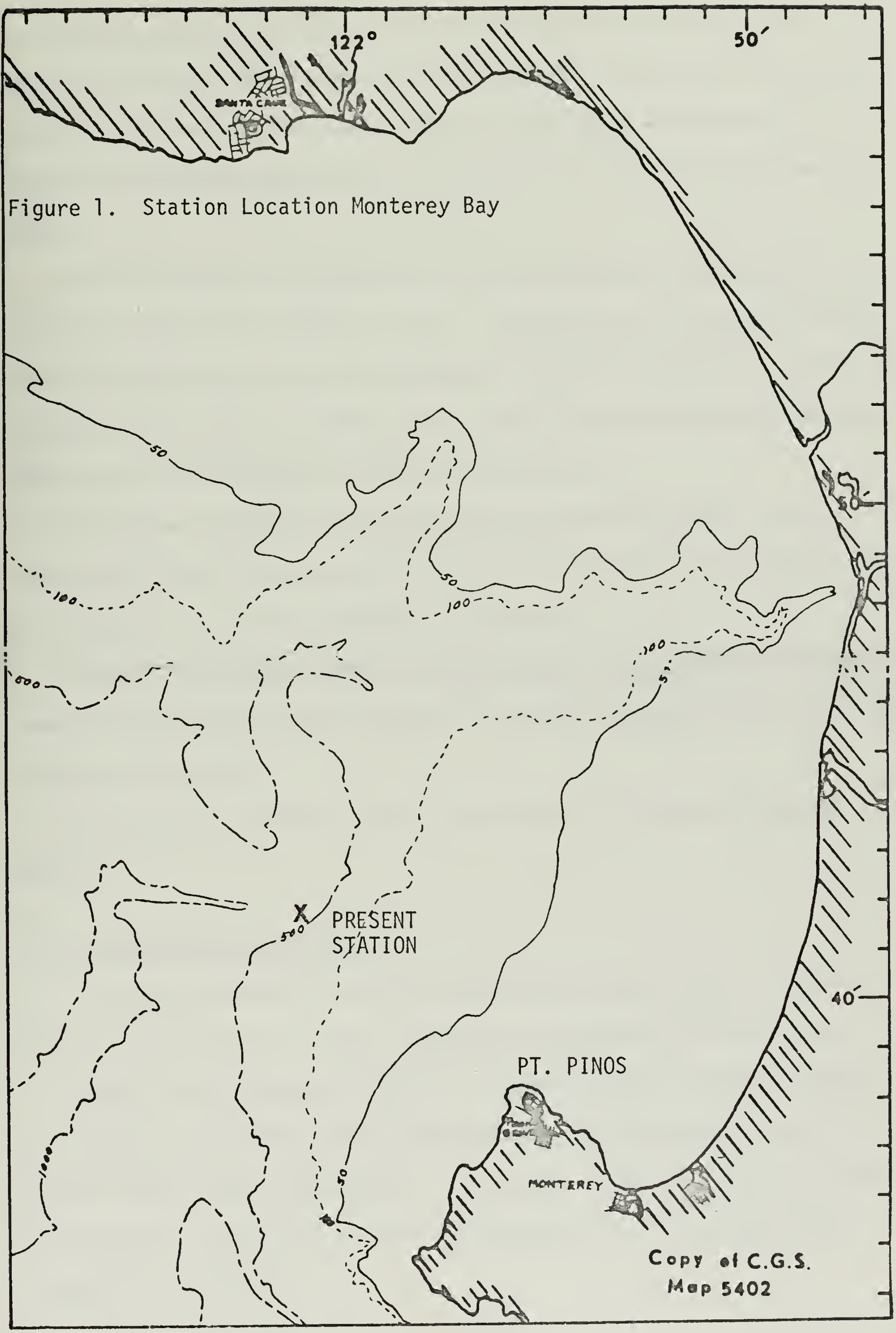

Figure 1. Station Location Monterey Bay

essentially constant voltage during each cast, thus eliminating the problem of voltage regulation from the surface. The battery pack could be used for three to four casts before it had to be recharged. At present this instrument package is limited to a depth of approximately 300 m.

A Bissett-Berman Telemetering Salinity-Temperature-Depth-Sound Velocity System Model 9040 was used. It can be set in various modes of operation depending on the environmental conditions measured. Table III (Appendix A) outlines the modes used. This instrument was operated and maintained by the NAVOCEANO detachment aboard ship.

A Sippican Expendable Bathythermograph System was used. It is described in detail by Labyak [14] and has an accuracy of ± 0.2 ^{o}C and ± 2 percent or 15 feet, whichever is greater.

A Model T 15-Channel Coulter Counter described by Shepard [20] was used for particulate matter analysis. A 100-μ diameter orifice was used on each 2 ml sample.

Hydrographic casts were made using standard Teflon-lined Nansen Bottles.

C. DATA COLLECTION PROCEDURE

A total of 48 casts were made during the 27 hour period that the station was occupied. Table I (Appendix A) summarizes these casts.

Due to the proximity of the XBT launcher to both the hydrographic and alpha meter winches, XBT drops could not be made while either of these winches were in operation. The distance between these two winches was such that they could be used simultaneously if instruments were lowered to only 250 m.

In order to facilitate the determination of relations between various parameters, all measurements were taken at the same depths. The sample depths in the upper layers were chosen closer together, since this is where the greatest gradients in the parameters under study were to be found.

Oxygen samples were drawn and fixed immediately after the completion of each hydrographic cast. The dissolved oxygen concentration was determined using a modified Winkler titration method [6].

Salinity was determined at sea using a Bissett-Berman Inductive Salinometer Model 6220.

Reactive phosphorus was determined using a Beckman Model DU-2 Spectrophotometer according to the method described by Strickland and Parsons [24].

Values of all data collected are listed in Appendix A. Appendices D and E present reproductions of XBT traces and S/T/D/SV traces respectively.

III. DATA ANALYSIS

A. STATION DATA

In choosing previous stations with which to compare the present study, two general locations were picked. The stations in Monterey Bay were chosen for their proximity to the present station in order to determine seasonal dependence of the various parameters. In order to determine location dependence, an area off Point Montara, approximately 50 n mi southwest of San Francisco Bay, was picked. A summary of weather conditions for all stations is givin in Table IX (Appendix B). Under the present heading is presented a summary of water conditions at each station. Figures 2 and 3 show the locations of these stations. The relative "clearness" of the water is defined such that "clear" water has an attenuation coefficient less than .357 m^{-1}, "relatively clear" water has an attenuation coefficient between .357 m^{-1} and .693 m^{-1}, and "relatively turbid" water has an attenuation coefficient greater than .693 m^{-1}.

The present station (36° 41.8 'N, 122° 02.8 'W) was occupied 16-17 June 1971. This station was in approximately 1700 m of water, 5.8 n mi off Point Pinos in Monterey Bay. The average sea surface temperature was 12.0 °C with a thermocline from 10 to 30 m. The surface layer was "relatively turbid" to a depth of 12 m, with "relatively clear" water below to a depth of 30 m, with "clear" water below this.

Yeske and Waer's station DELTA was at the same location as the present station. Two days were chosen for comparison: 23 August 1969 at 0945 and 30 August 1969 at 1730. The sea surface temperature was 13.7 °C with a thermocline from 10 to 12 m. The surface layer was "relatively turbid" to a depth of approximately 15 m with "clear" water below [26].

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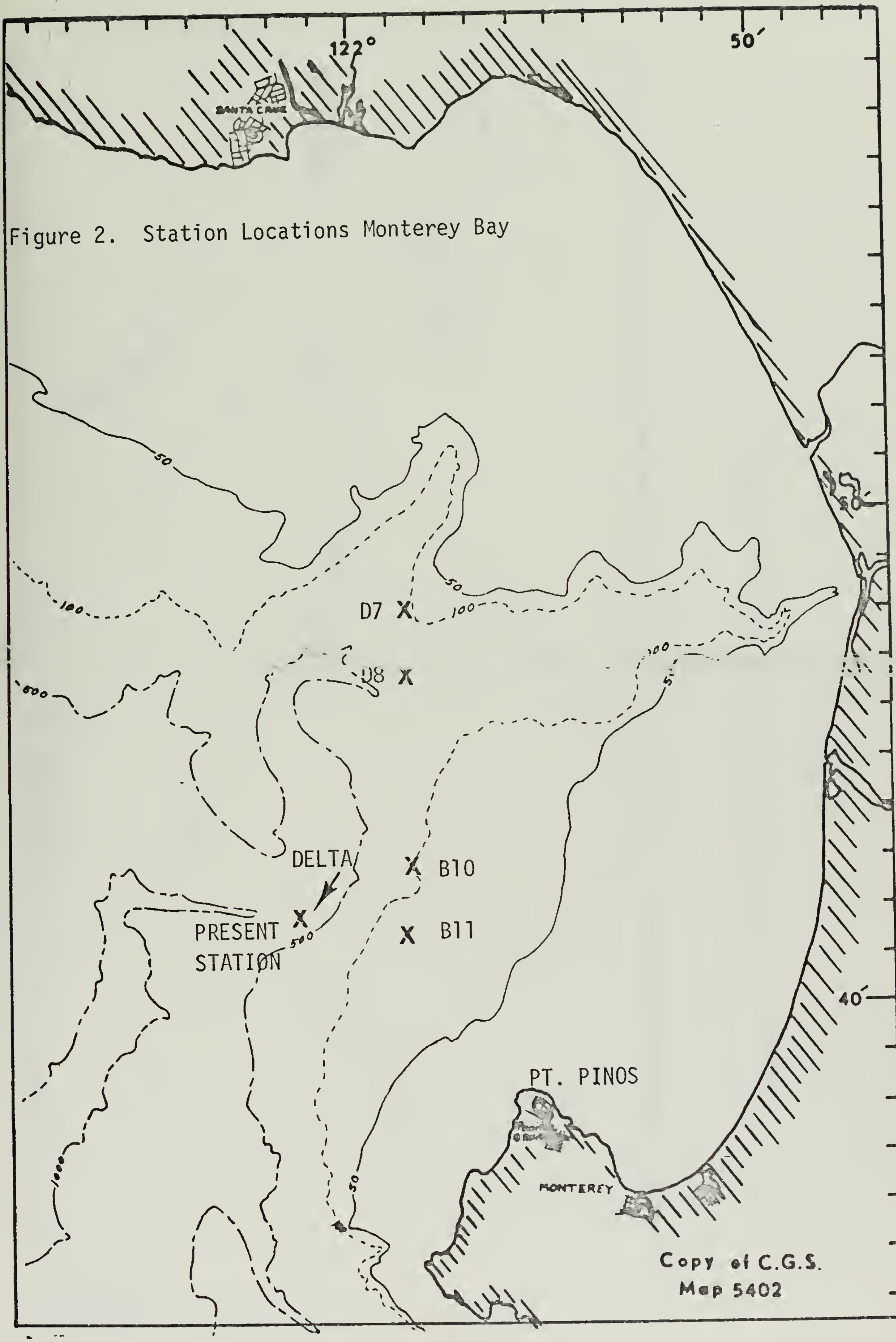


Figure 2. Station Locations Monterey Bay

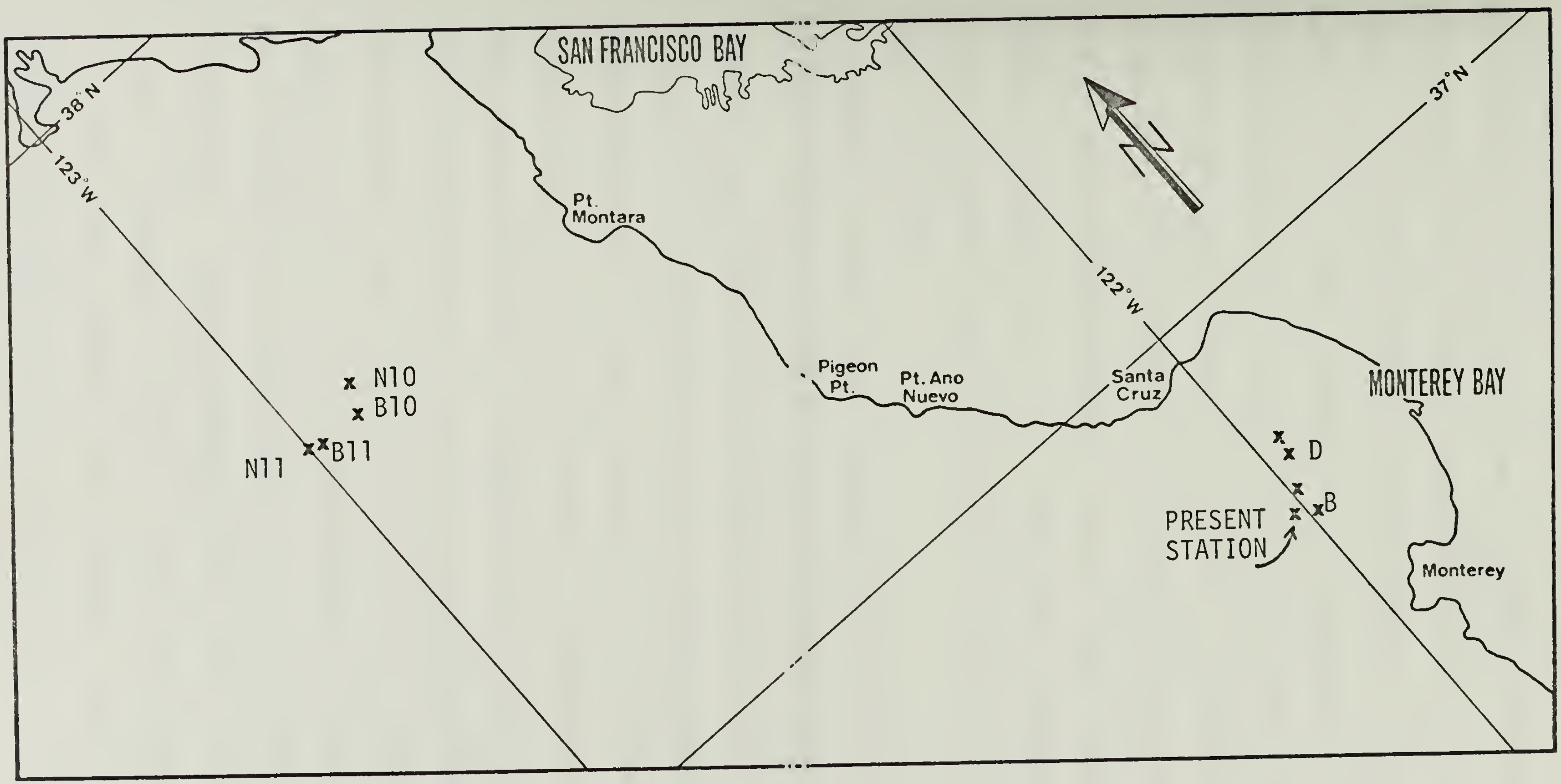


Figure 3. Station Locations Central California Coast.

Labyak's Monterey Bay stations D7 (36° 48.0' N, 121° 59.0' W) and D8 (36° 46.7' N, 121° 59.0' W) were occupied 12 May 1969. These stations are in 342 and 714 m of water, respectively, 10 n mi from Point Pinos, and 6 n mi shoreward from the present station. The sea surface temperature was 11.1 °C with a thermocline at approximately 25 m. The water was "relatively clear" throughout the water column. Stations N10 (37° 32.2' N, 122° 54.5' W) and N11 (37° 32.5' N, 122° 58.8' W) were occupied 16 May 1969. These stations are in 95 and 278 m of water, respectively, 25 n mi west of Point Montara. The sea surface temperature was 10.7 and 11.4 °C, respectively, with a thermocline at approximately 15 m. The surface layer was "relatively turbid" to a depth of 18 m with "clear" water below [14].

Shepard's Monterey Bay stations B10 (36° 42.6' N, 121° 59.4' W) and B11 (36° 41.2' N, 121° 59.2' W) were occupied 30 April 1970. These stations are in 480 and 108 m of water, respectively, 4 n mi from Point Pinos, and 2.5 n mi shorward from the present station. The sea surface temperature was 10 °C with a thermocline at approximately 15 m. The surface layer was "relatively turbid" to a depth of 20 m with "relatively clear" water below this to a depth of 65 m, with "clear" water below. Station K9 (37° 31.2' N, 121° 58.0' W) and K10 (37° 32.3' N, 122° 58.0' W) were occupied 4 May 1970. These stations are in 167 and 755 m of water, respectively, 24 n mi west of Point Montara. The sea surface temperature was 11.9 and 12.3 °C, respectively, with a thermocline at 20 and 14 m, respectively. This area showed "clear" water to a depth of 100 m [20].

All of the above stations were taken during the Upwelling Period and exhibit water conditions that one might expect to find. The following stations were taken during the Oceanic Period.

Baker's Monterey Bay stations B10 (36° 43.0' N, 121° 58.9' W) and B11 (36° 41.4 ' N, 121° 59.2' W) were occupied 11 September 1969. These stations are in 320 and 113 m of water, respectively, 4 n mi from Point Pinos, and 2.5 n mi shoreward from the present station. The sea surface temperature was 14.6 °C and the water column was isothermal to 100 m. This area showed "clear" water at all depths. Stations K9 (37° 32.3' N, 121° 52.5' W) and K10 (37° 32.3' N, 121° 56.0' W) were occupied 12 November 1969. These stations are in 90 and 108 m of water, respectively, 25 n mi west of Point Montara. The sea surface temperature was 14.5 °C with a thermocline at 20 m. This area showed "relatively clear" water to 100 m with a tongue of "clear" water between 20 and 40 m [2].

Soluri's Monterey Bay stations B10 (36° 42.8' N, 122° 59.1' W) and B11 (36° 42.1' N, 122° 59.1' W) were occupied 5 November 1970. These stations are in 247 and 109 m of water, respectively, 5 n mi from Point Pinos, and 2 n mi shorward from the present station. The sea surface temperature was 13.3 °C with a thermocline at approximately 65 m. This area showed "clear" water to a depth of 100 m. Stations K9 (37° 32.0' N, 122° 58.1' W) and K10 (37° 32.0' N, 122° 03.6' W) were occupied 2 November 1970. These stations are in 210 and 600 m of water, respectively, 25 n mi west of Point Montara. The sea surface temperature was 12.9 and 13.5 °C, respectively, with a thermocline at approximately 40 m. The upper 15 m at station K9 was "relatively clear" with "clear" water below, while station K10 exhibited "clear" water to a depth of 100 m [23].

A summary of water characteristics for all stations can be found in Table X (Appendix C).

B. OCEANOGRAPHIC PARAMETERS

1. Physical Parameters

a. Particulate Matter Analysis

For a given body of water one may assume that the primary factor affecting light attenuation will the particulate matter present causing scattering. Yeske and Waer [26], Labyak [14], Shepard [20], and Baker [2] have related light attenuation and particle count with some degree of success. Figure 4 shows plots of particle count against depth for varying particle diameters (1.6 to 32 μ). All of the profiles show similar shapes, which relate well with the alpha profile for the same water column. The larger particles are more sensitive indicators of light attenuation than are the smaller ones.

Bader [1] observed that many natural collections of small particles such as mineral and organic particles suspended in sea water have hyperbolic distributions. He found that a log-log plot of equivalent spherical diameter versus cumulative particle count for sea water samples from Abaco Bight, Little Bahama Bank, resulted in two lines, one with a slope of -1.45 (particle diameters greater than 4.6 μ) and the other with a slope of -.88 (particle diameters less than 4.6 μ). These appear as dashed lines on Figures 5 through 8. The general slope of these plots (log count against channel number) closely follows Bader's line of slope -1.45.

Variations from the "normal" hyperbolic distribution are indications of the presence of particles in excess of what could be considered a "background" count of particles in sea water. Two areas of interest are the 4.00-μ size (channel 9) in Figures 5 and 6. This size particle was distributed uniformly over the entire water column to

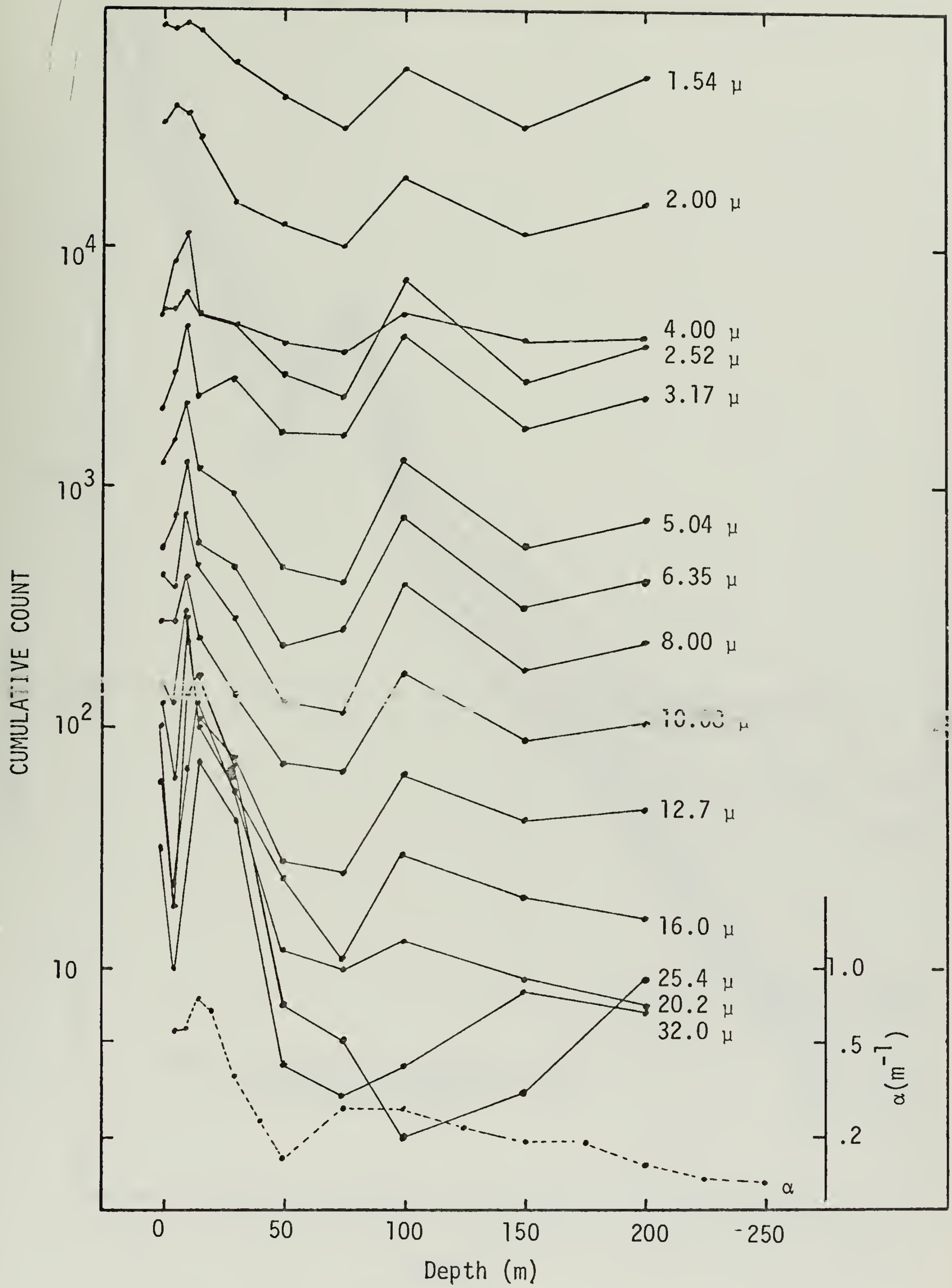


Figure 4. Count versus Depth, Time: 1235

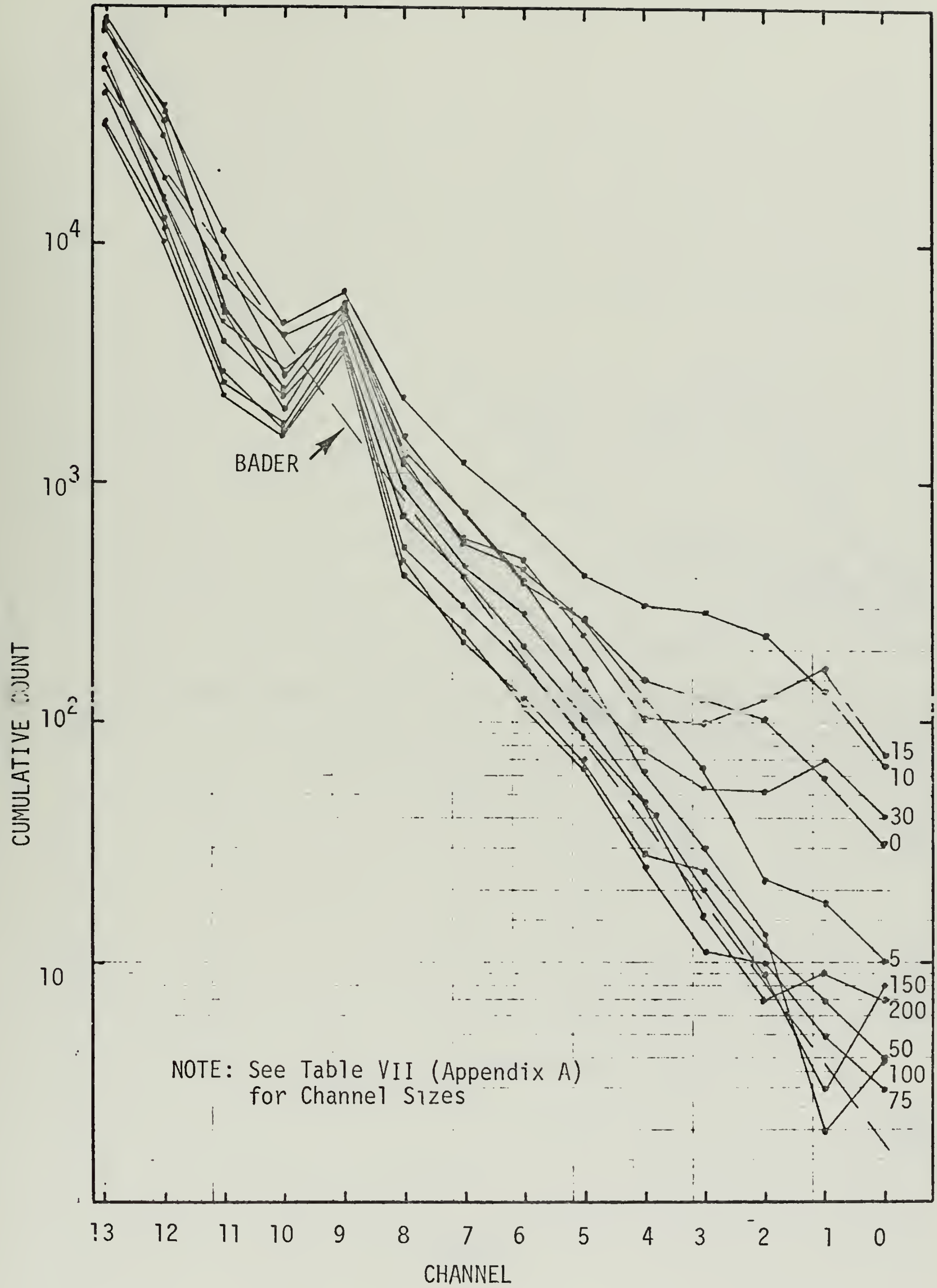


Figure 5. Cumulative Count versus Size, Time: 1235

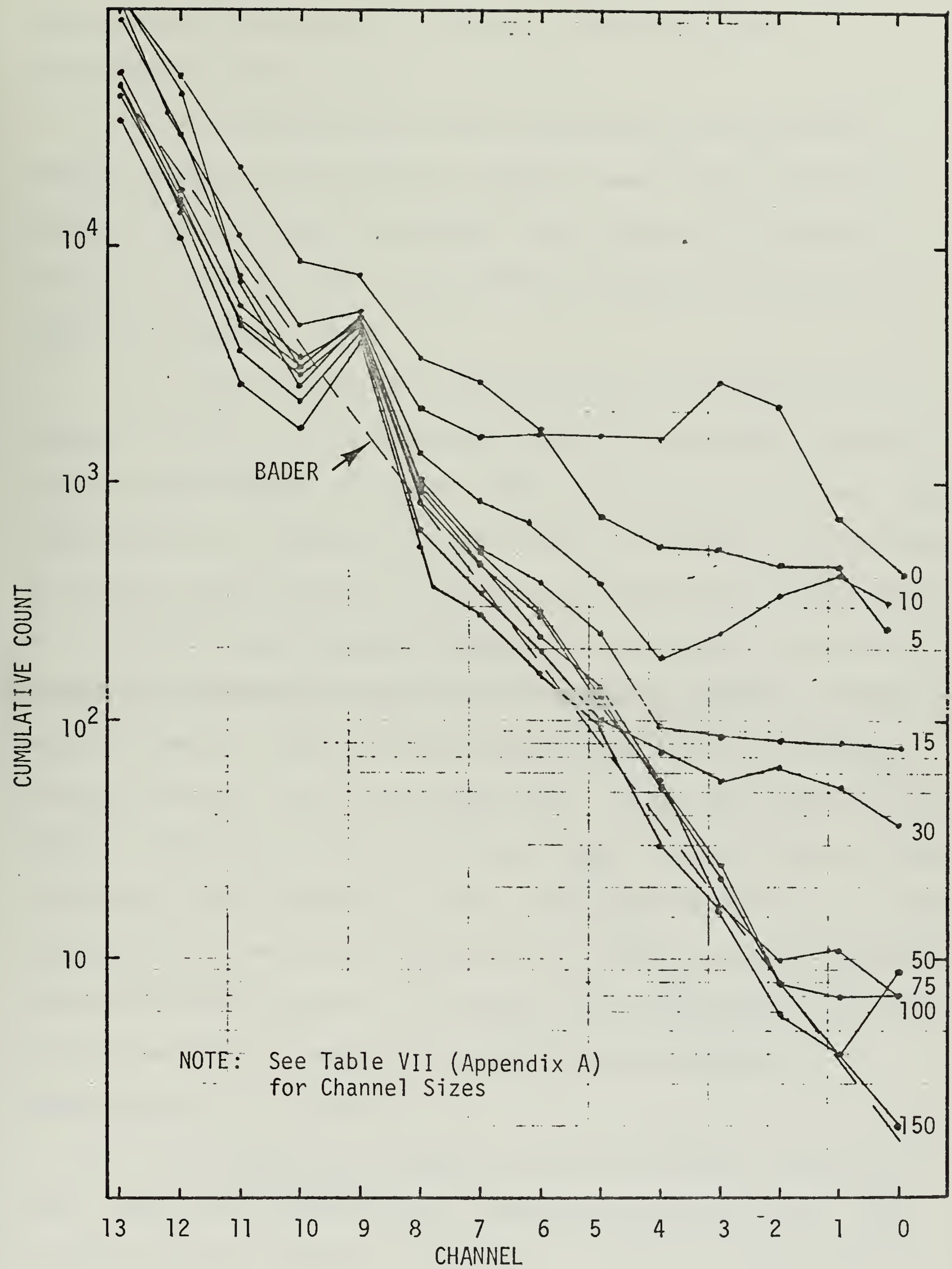


Figure 6. Cumulative Count versus Size, Time: 1725.

200 m, and was probably due to a bloom of plankton of this characteristic size.

The larger particle distributions also vary from this "normal" hyperbolic distribution. Although some of this variation is the result of statistical uncertainty in the counts, it is also an indication of the presence of many different particles that can be found in an upwelling region.

It is of interest to note the plots for the upper 10 m of the water column. For the larger particles (4 μ and above), a distinctive grouping of plots is evident. These large particles are most likely phytoplankton that reside in the upper layer of the ocean. The positions of the three sample depths, 0, 5, and 10 m, compared with the positions of all the other sample depths throughout the day, reveal the vertical variation of particulate matter over the period of the casts. In the middle of the day (Figure 5) the distribution of particles throughout the water column is seen to be rather mixed. As the day passes (Figures 6 and 7), the particle count in the upper layer increases while the count in the lower layers decreases. Late at night (Figure 7) there is a large concentration of particles in the upper 10 m, while the lower layers are relatively void of particles. In Figure 8, the next morning, one can see how the particles are beginning to migrate upward, approaching the representation as in Figure 5.

A parameter more realistic than particle count is particle size. Soluri [23] related alpha to cumulative particle volume. This is valid since the cumulative volume of the particles can be translated into a projected cross-sectional area, which is what determines how much light will be attenuated. Soluri also compared alpha with cross-sectional area. The method of area calculation is very important. The area must

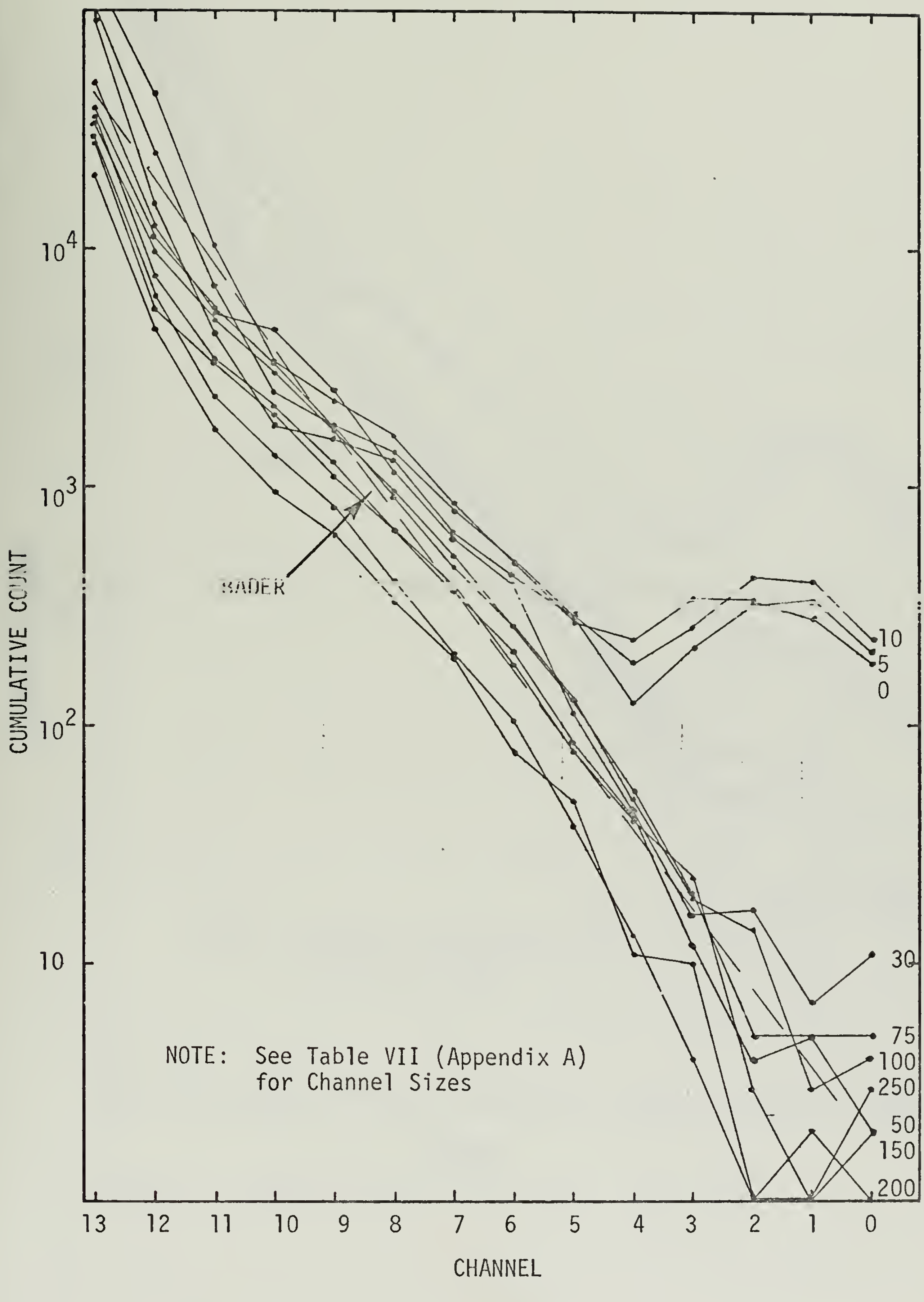


Figure 7. Cumulative Count versus Size, Time:2220

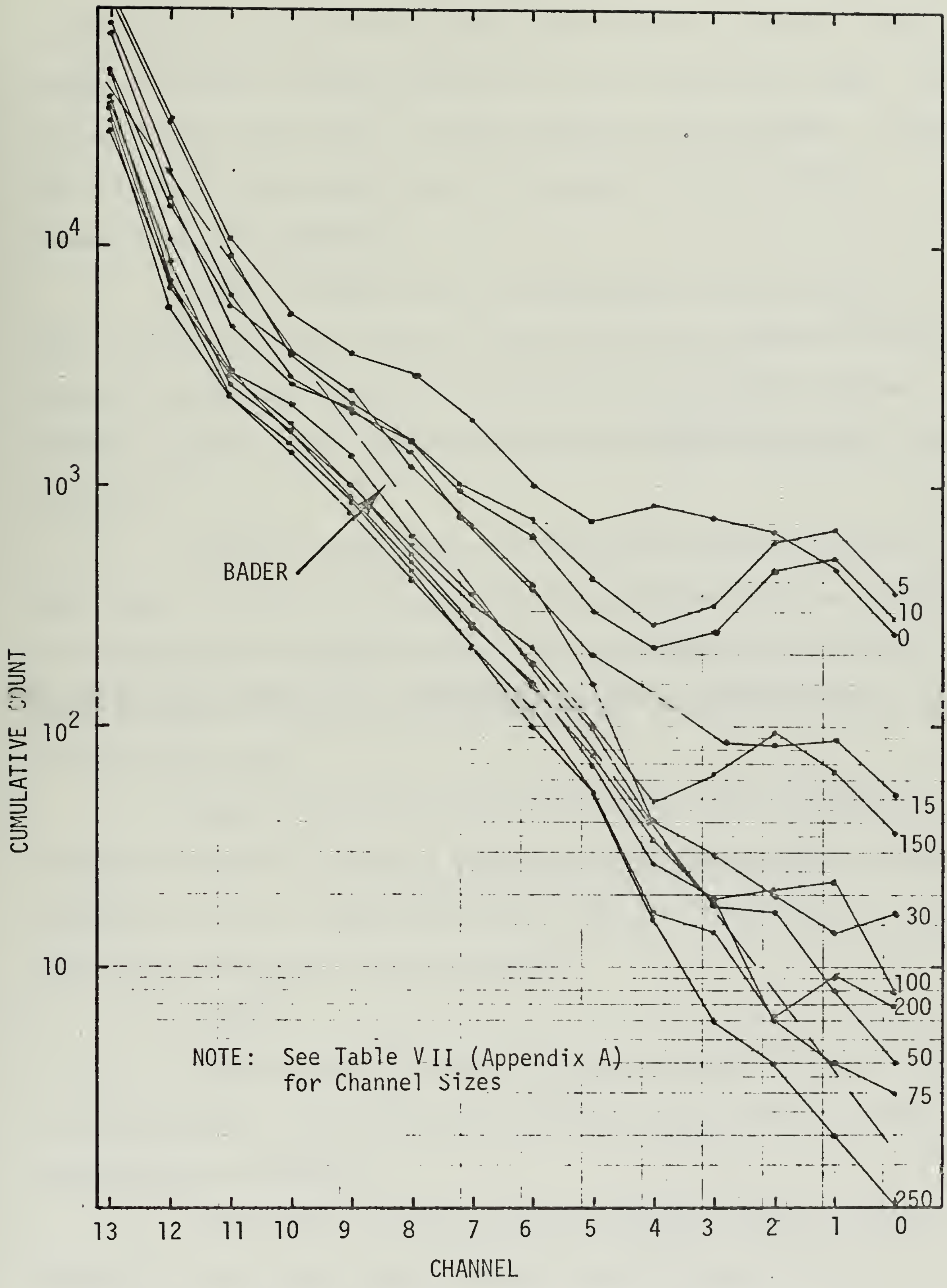


Figure 8. Cumulative Count versus Size, Time: 0845

be calculated for each particle size, then summed for the entire sample. Figures 9 through 12 compare volume, area, and alpha against depth. The shapes of these curves show a relation between these parameters. Figure 13 is a plot of alpha against area and suggests a linear relation between these two parameters.

Figure 14 shows plots of alpha against area for Soluri's data. Although no clear relation could be found for either the Monterey Bay or Point Montara stations, the data points were grouped together. At these stations, Soluri found the water to be either "relatively clear" or "clear".

Figure 15 shows plots of alpha against area for Shepard's data. Again for the Point Montara stations where the water was "clear", all of the data was grouped together. For the Monterey Bay stations, where the water varied from "relatively turbid" to "clear", a good relation can be seen.

Figure 16 presents all of these various plots together. Although the spread is large, a definite relation between alpha and area can be seen. It is interesting to note that the data points for "clear" water agree well with all the other data.

b. Density

While particulate matter in water determines the amount of light attenuation, its distribution within the water column is greatly dependent upon the density.

Figure 17 is a plot of log alpha against vertical density gradient. As one would expect, alpha in general inreases with an increase in density gradient. Yeske and Waer [26] and Baker [2] found high levels of beam attenuation in the thermocline and pycnocline. With

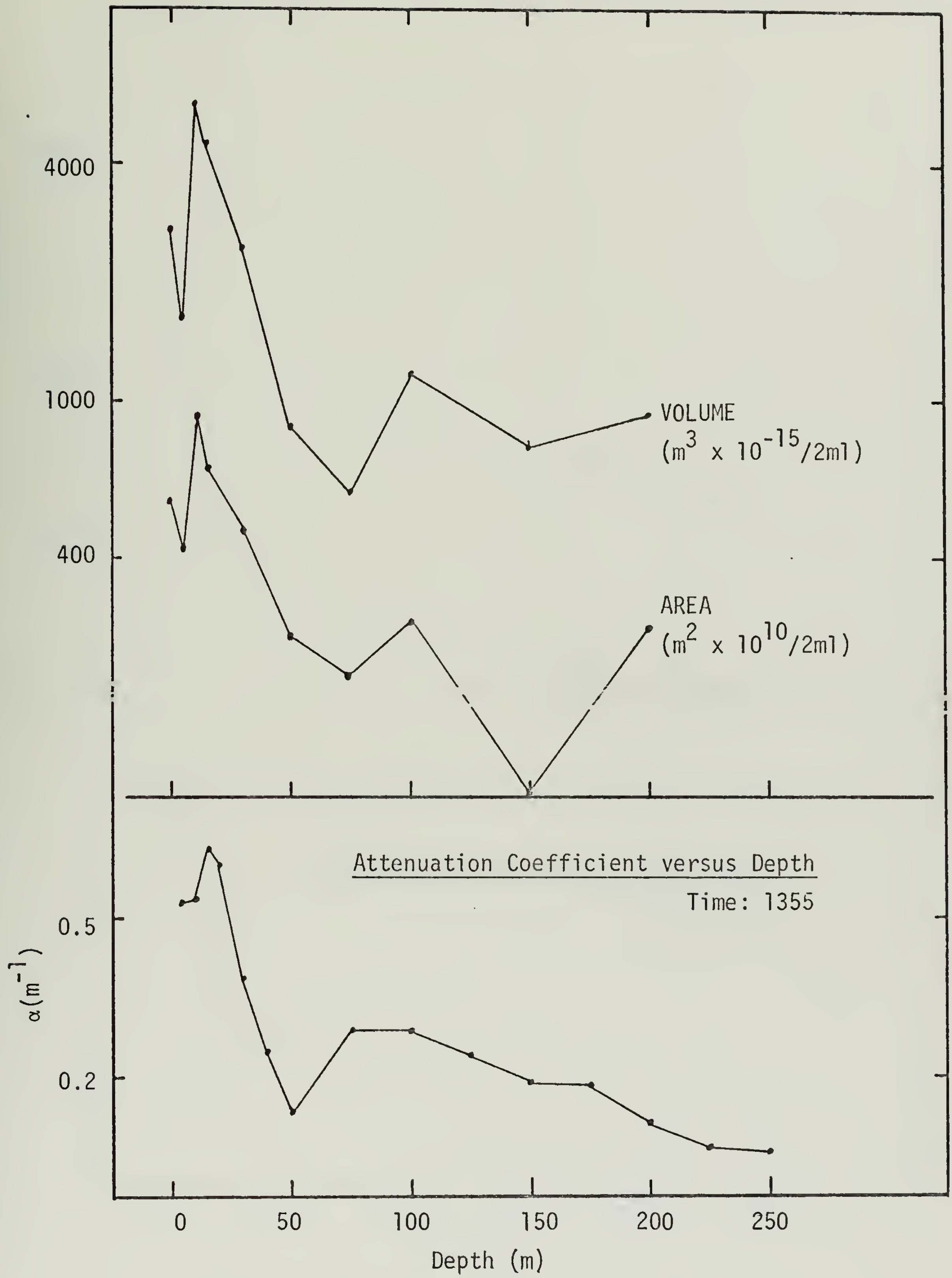


Figure 9. Size versus Depth, Time: 1235

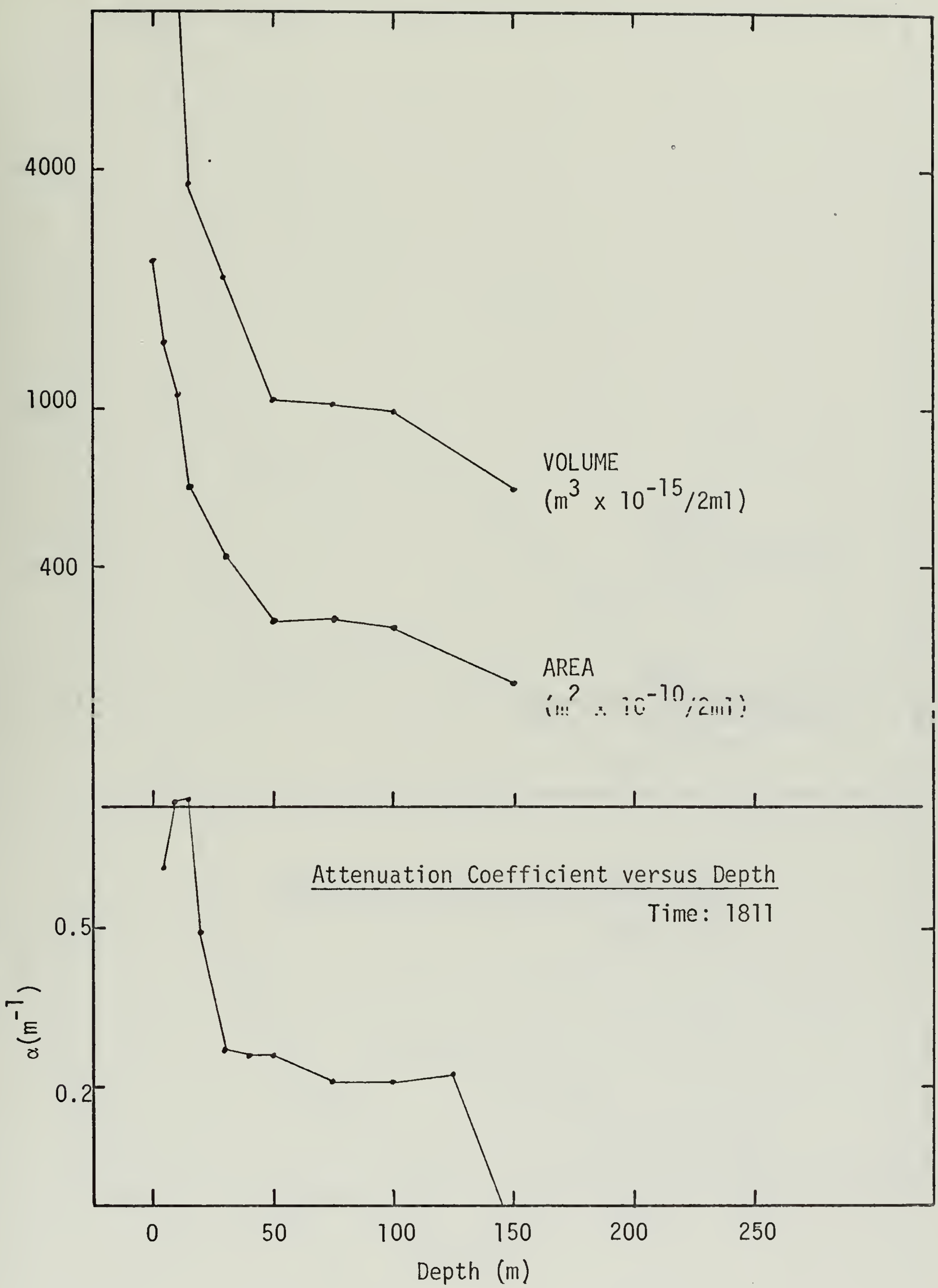


Figure 10. Size versus Depth, Time: 1725.

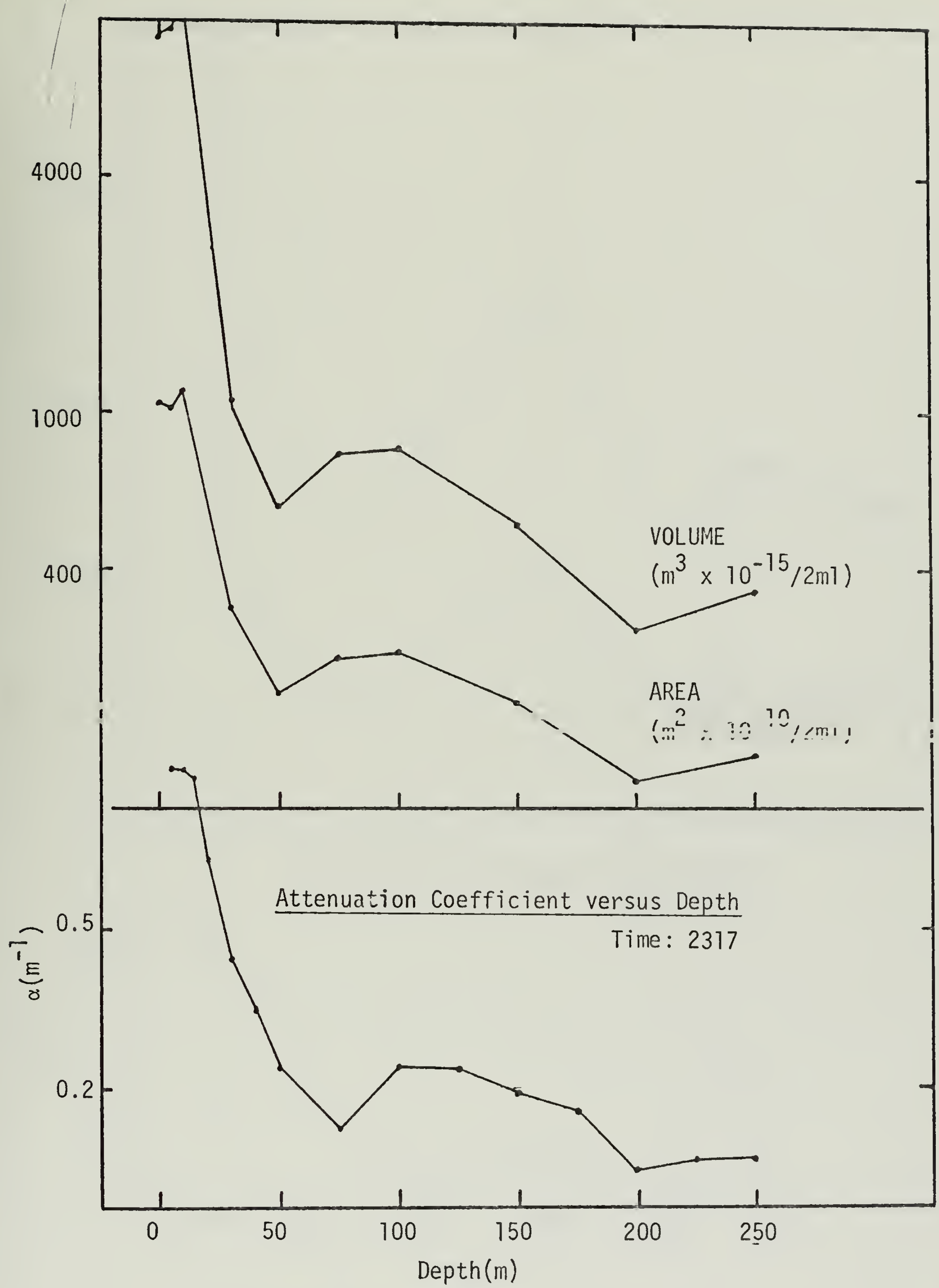


Figure 11. Size versus Depth, Time: 2220

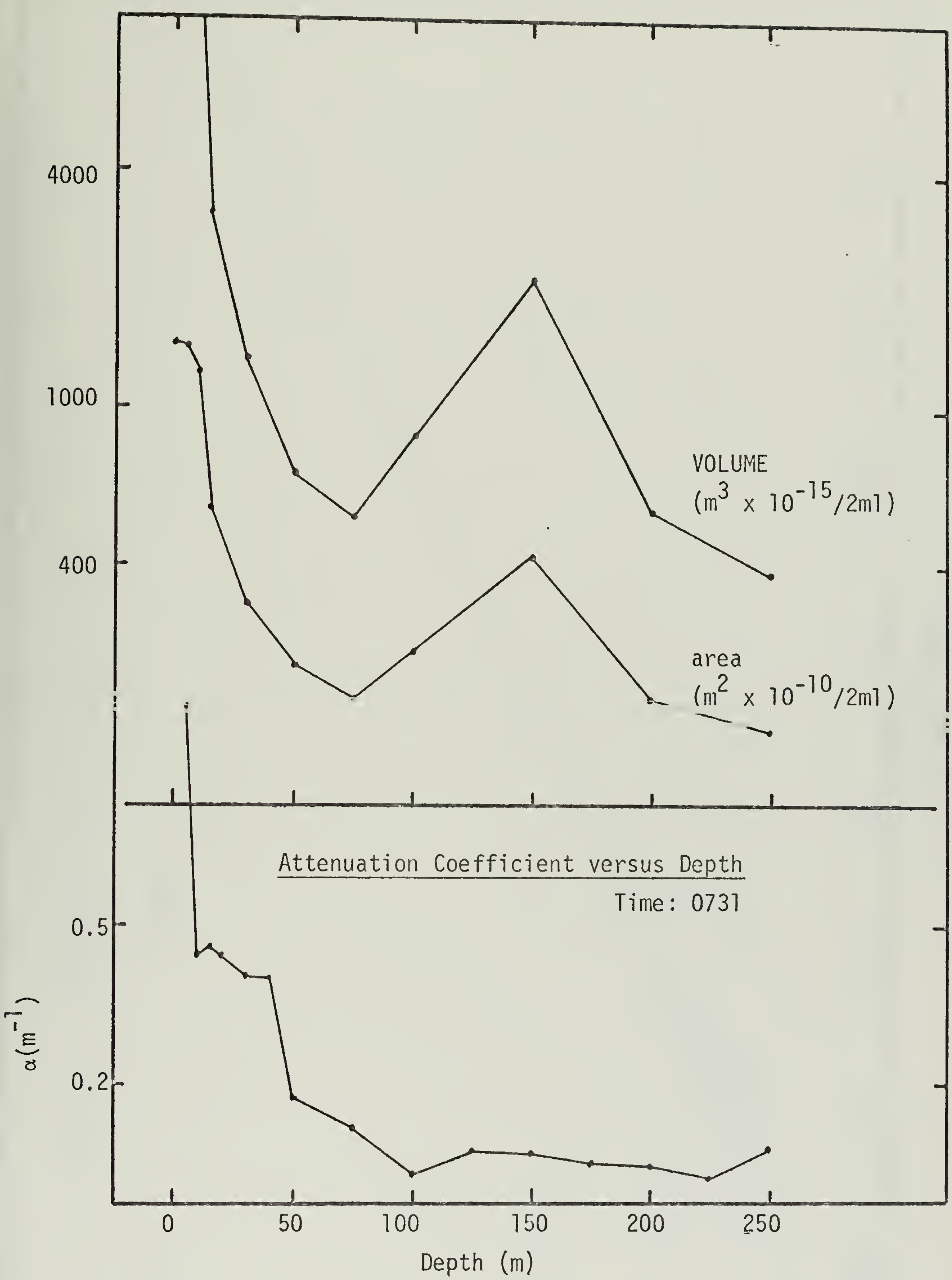


Figure 12. Size versus Depth, Time:0845.

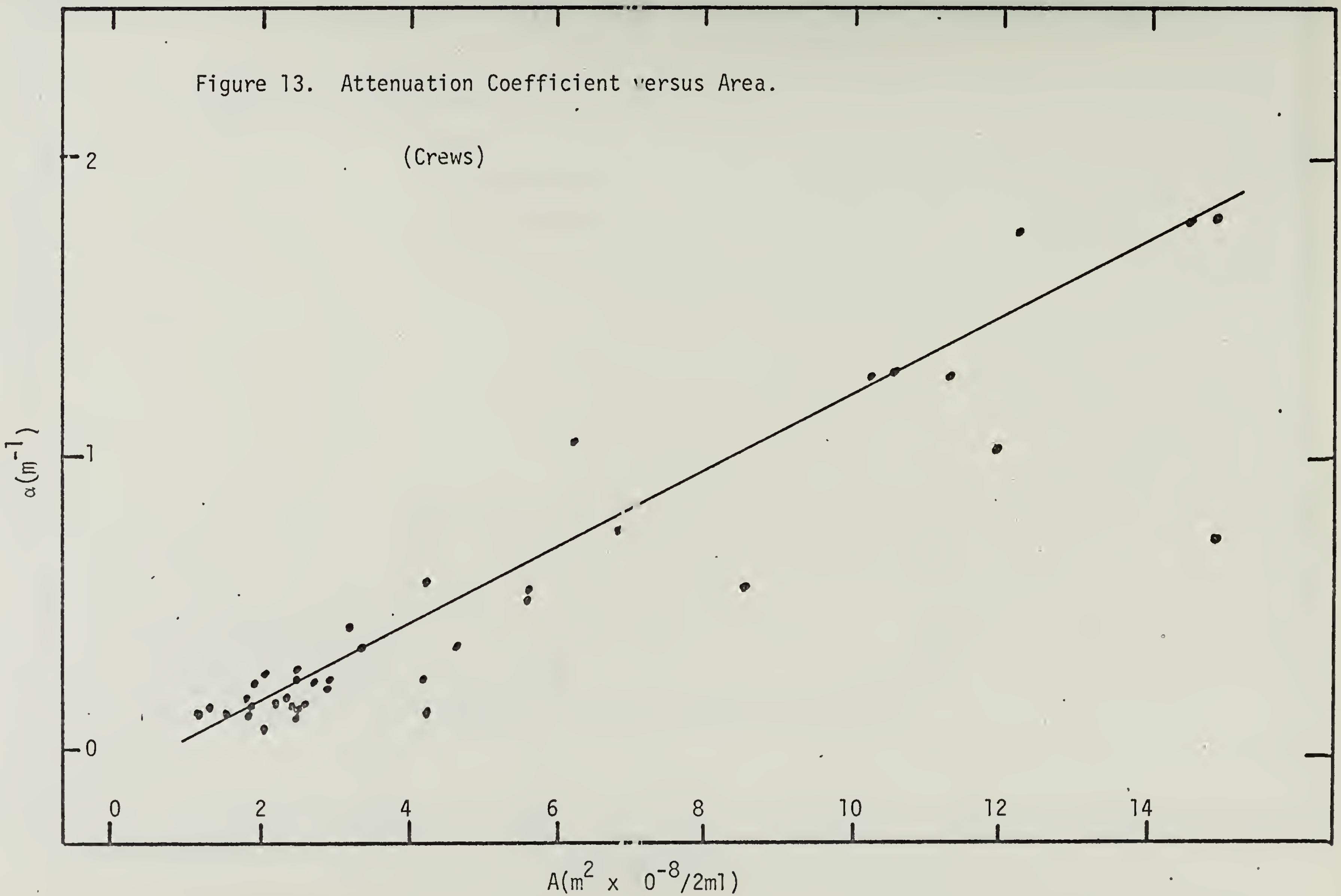


Figure 13. Attenuation Coefficient versus Area.

(Crews)

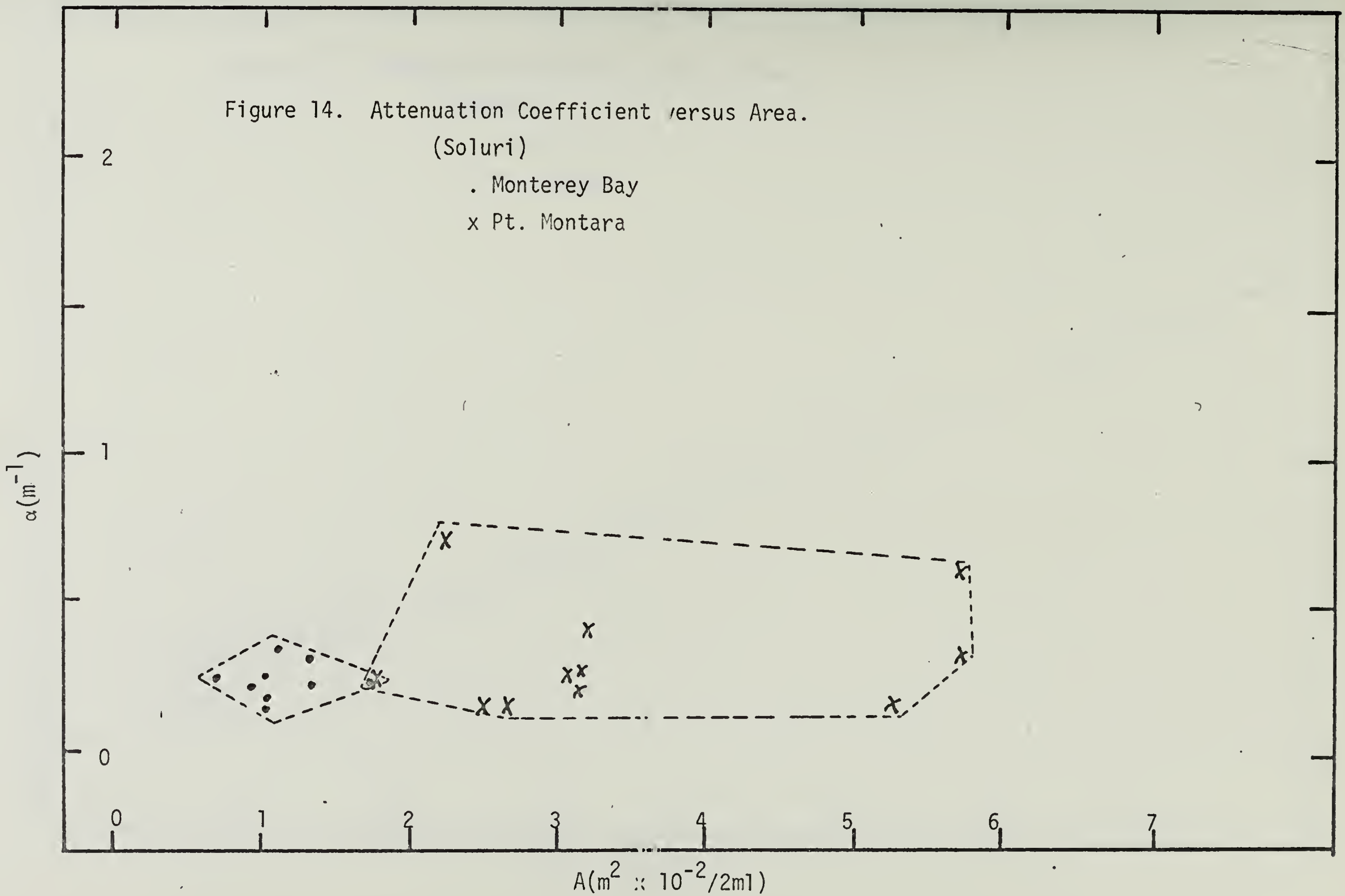


Figure 14. Attenuation Coefficient versus Area.
(Soluri)

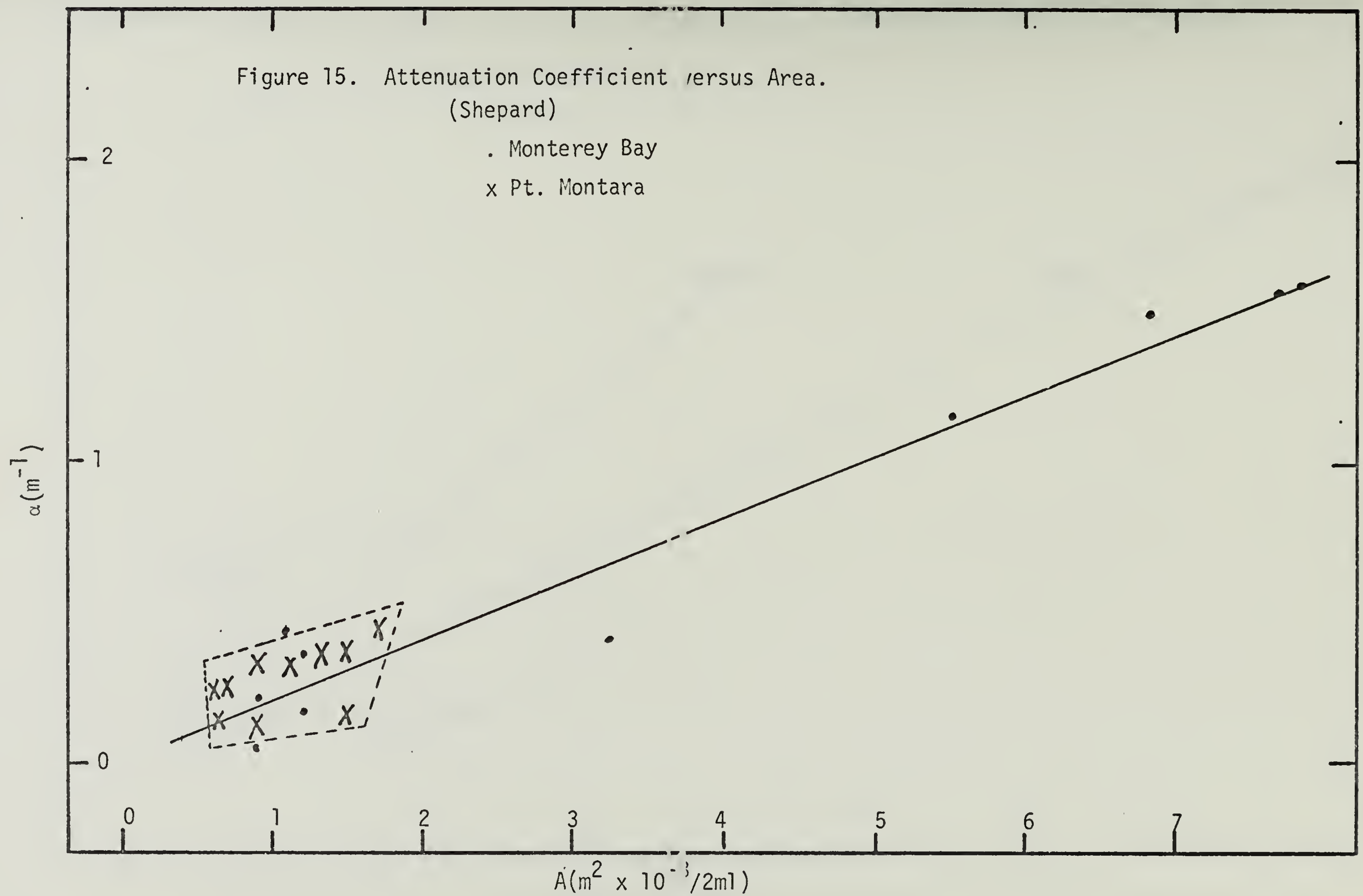


Figure 15. Attenuation Coefficient versus Area.
(Shepard)

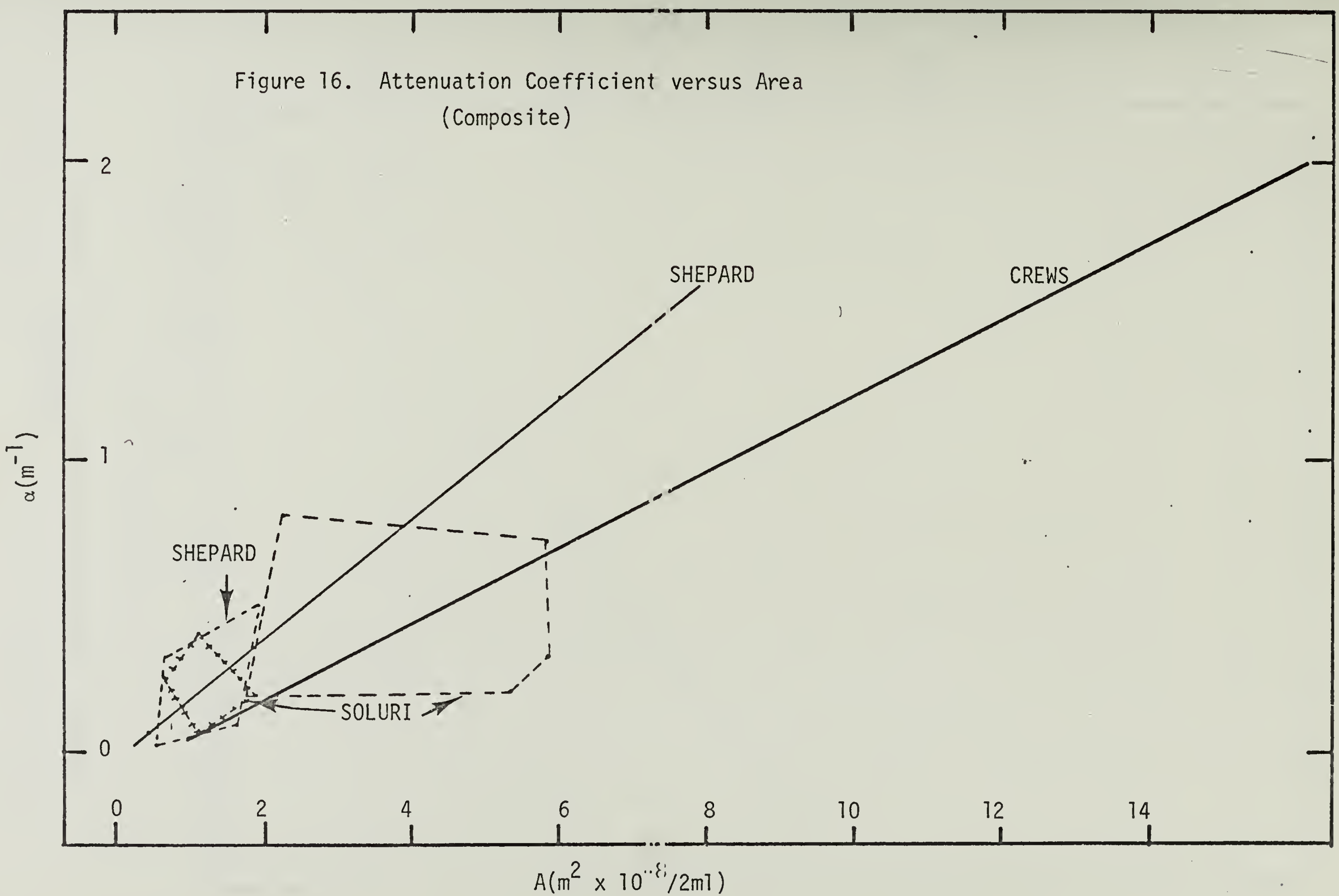


Figure 16. Attenuation Coefficient versus Area (Composite)

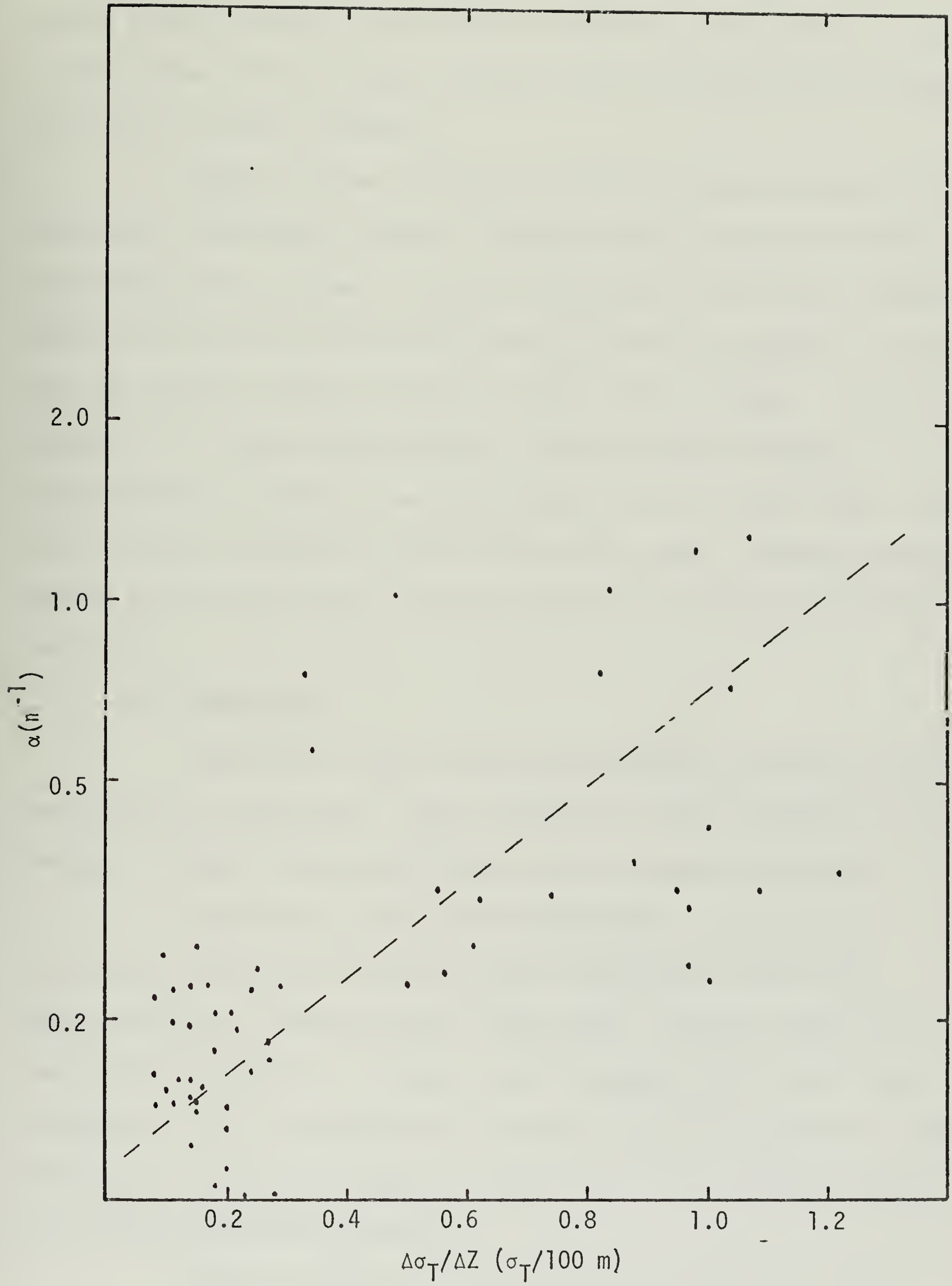


Figure 17. Attenuation Coefficient versus Density Gradient.

a small density gradient many different particles can be spread out over a water column, while in large gradients many particles tend to accumulate within short vertical distances.

Figure 18 shows a relation between log alpha and density for the present station data; Figure 19 shows similar relations for data collected by Yeske and Waer. Figure 20 shows the relation for Shepard's Monterey Bay station data, while Figure 21 reflects a grouping of such data for the Point Montara stations, "clear" water stations. Figure 22 presents all of these plots together. The plots that show good relations (Crews, Yeske and Waer, and Shepard) have similar slopes. The plots for Crews and Yeske and Waer have similar bends. Shepard's Point Montara data has too large a spread to enable us to reach any definite conclusions.

c. Temperature

Temperature is one of the best parameters with which to relate the attenuation coefficient. First, density is highly dependent on temperature. Second, temperature is the easiest parameter to measure.

Plots of log alpha against temperature for the present station data (Figure 23) as well as data from Shepard (Figure 24), Labyak (Figure 25), Yeske and Waer (Figure 26), and Baker (Figure 27) show apparent relations. As before, data obtained from "clear" water (Figures 24, 25, 27, and 28) tend to group. The curve from Baker's data (Figure 27) reflects the tongue of "clear" water found between 20 and 40 m at the Point Montara stations.

Figure 29 presents all of these plots together. If the data which did not relate is disregarded, the positive slopes for the data of Crews, Shepard,Yeske and Waer, and Baker appear to be very similar.

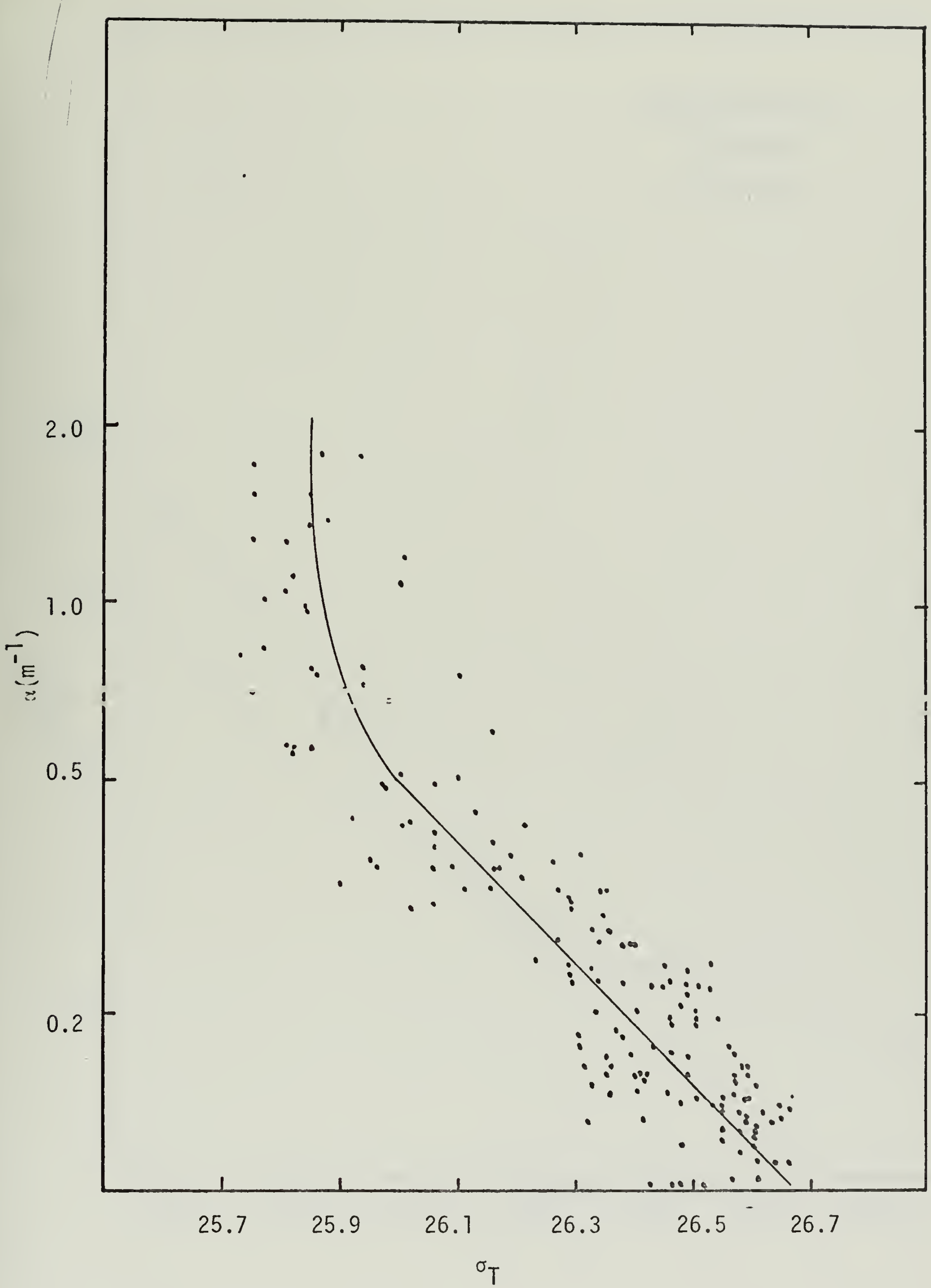


Figure 18. Attenuation Coefficient versus Density (Crews).

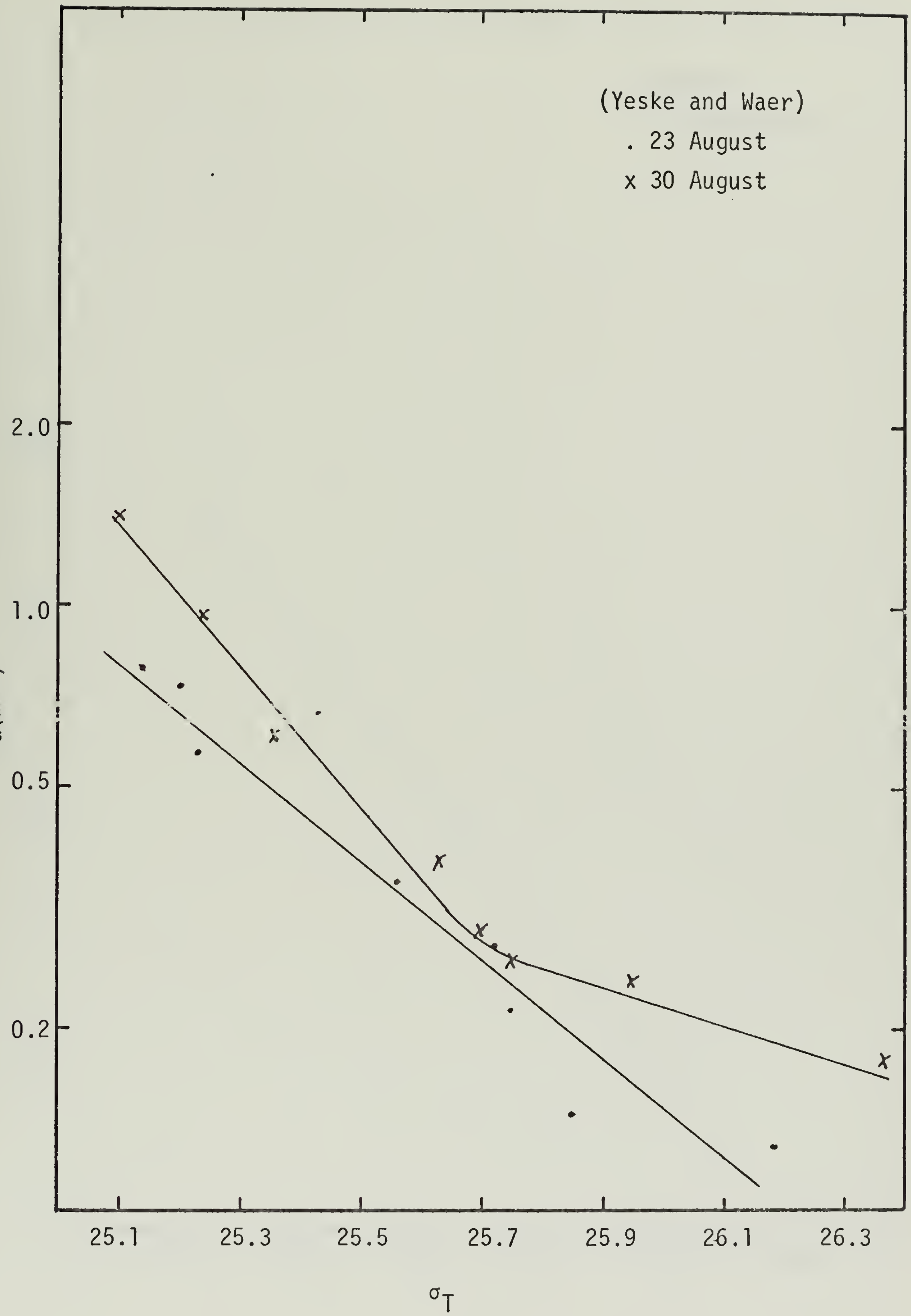


Figure 19. Attenuation Coefficient versus Density.

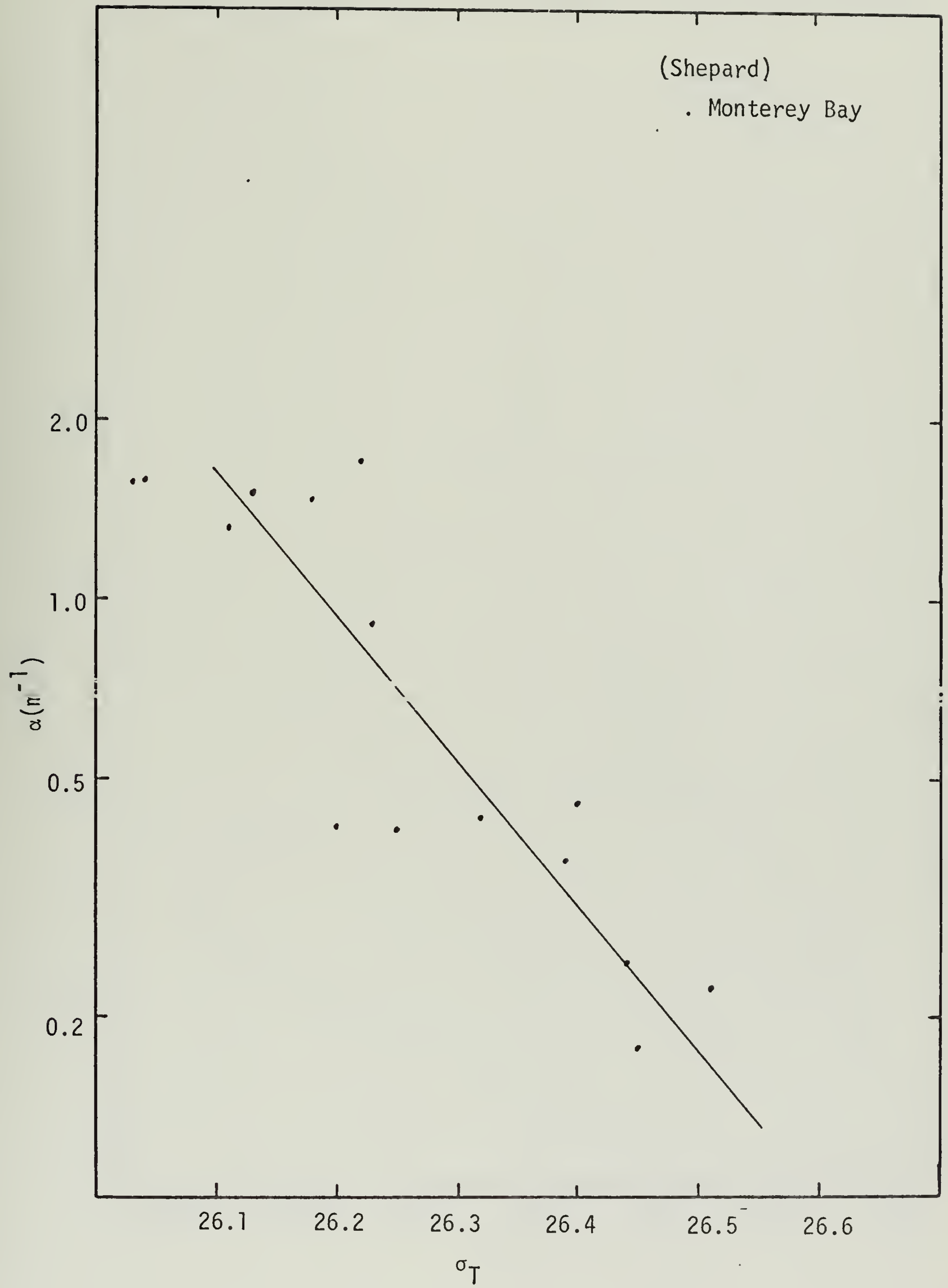


Figure 20. AttenuationCoefficient versus Density

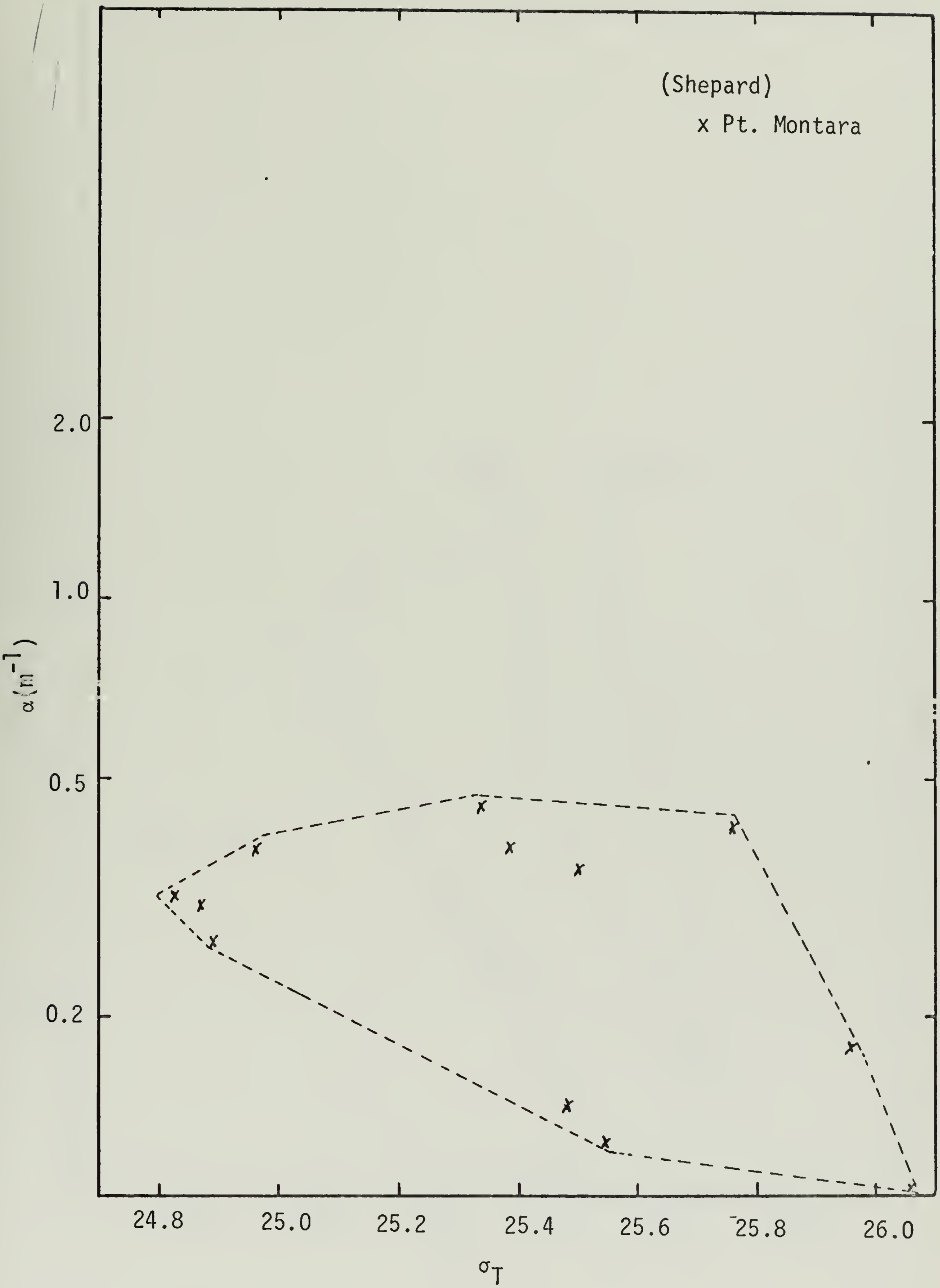


Figure 21. Attenuation Coefficient versus Density

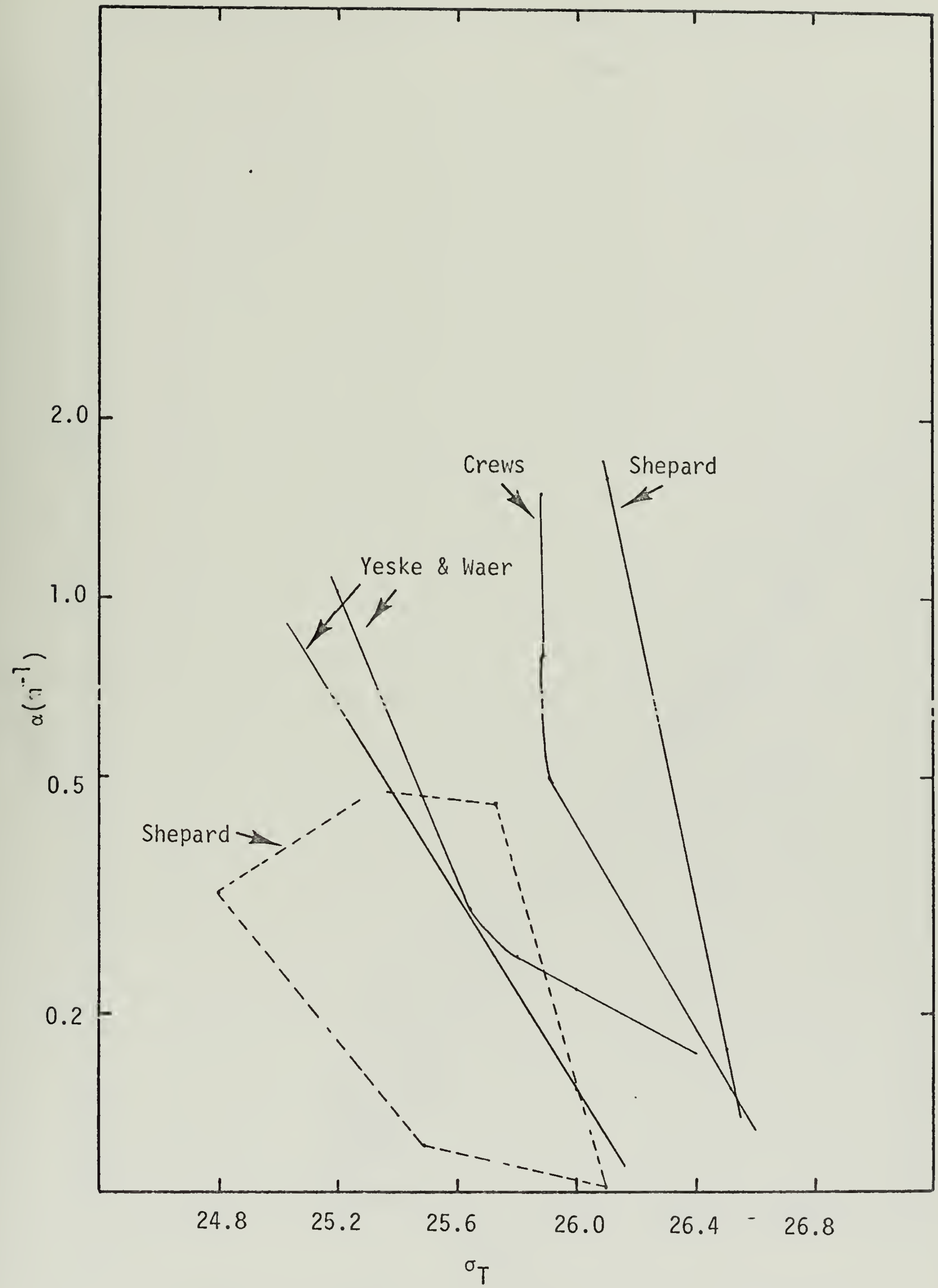


Figure 22. Attenuation Coefficient versus Density (Composite)

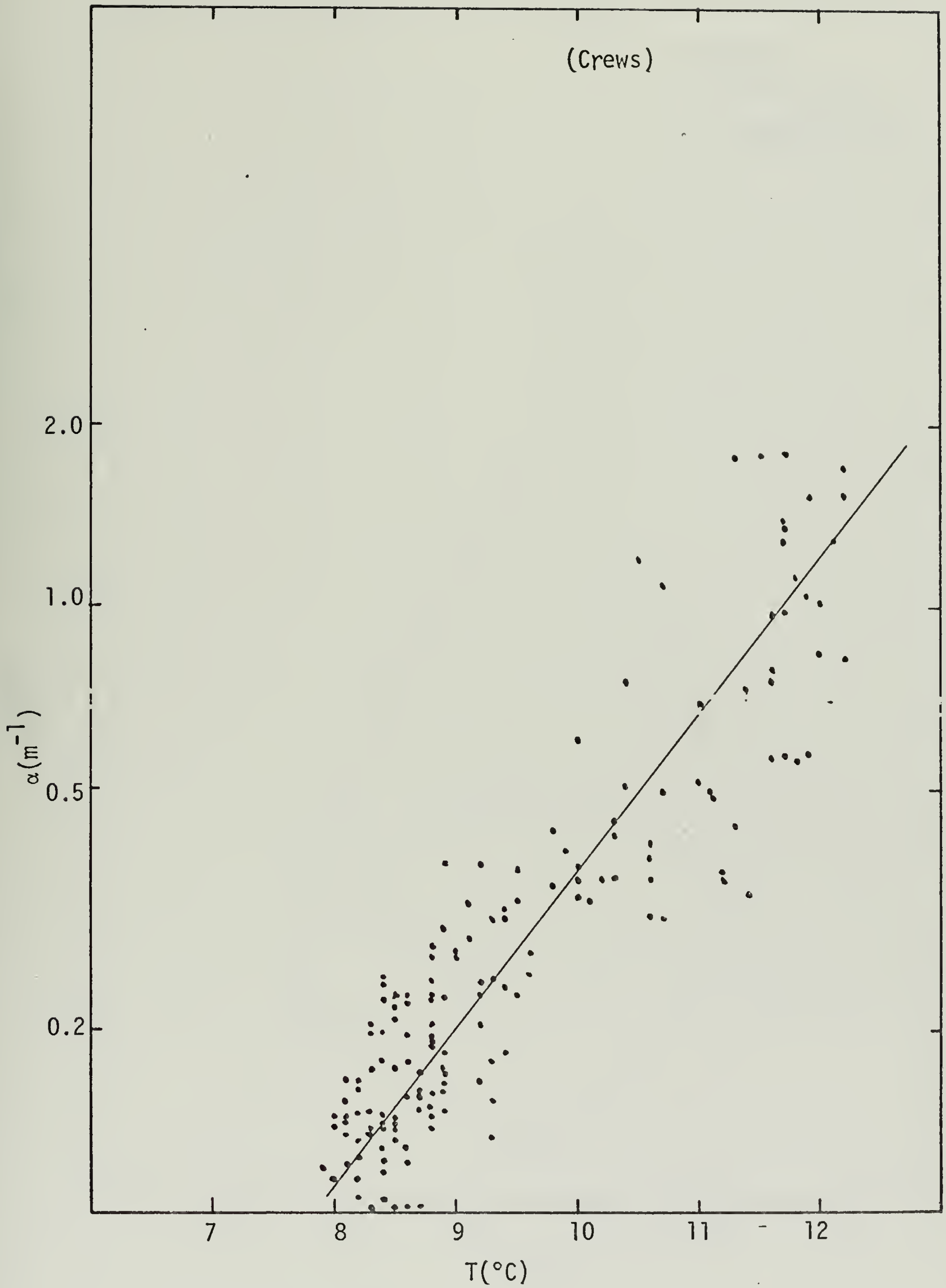


Figure 23. Attenuation Coefficient versus Temperature.

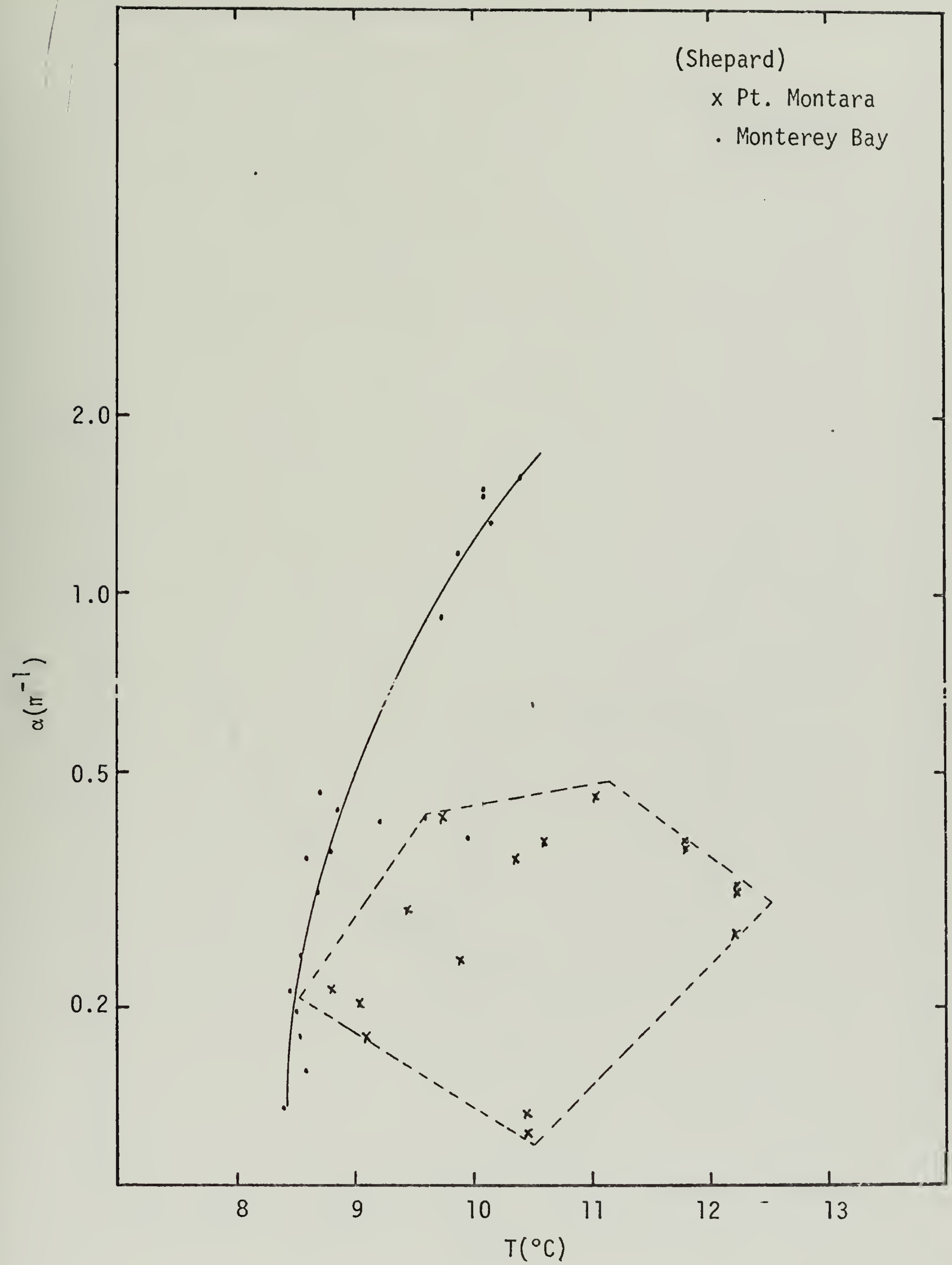


Figure 24. Attenuation Coefficient versus Temperature.

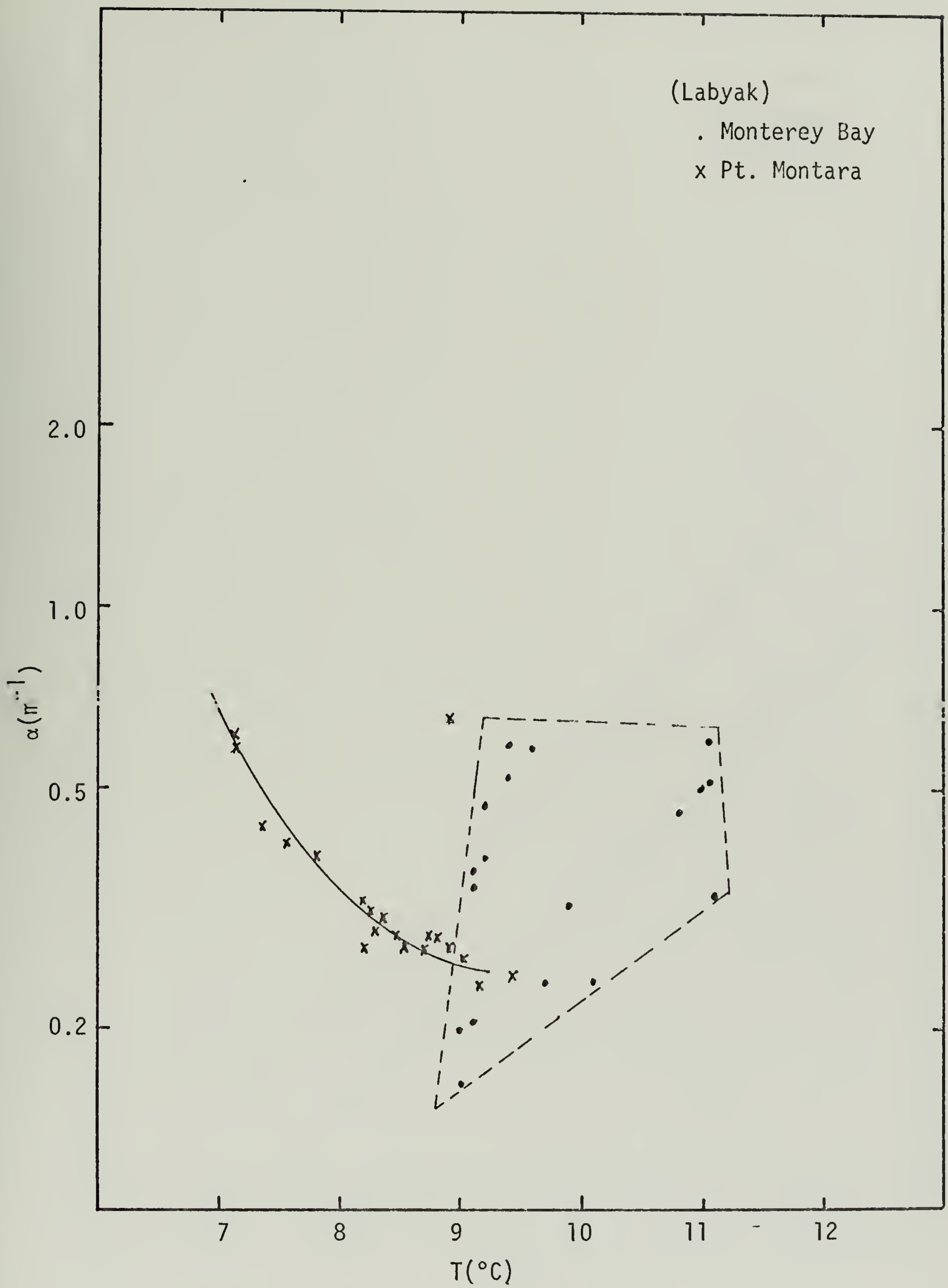


Figure 25. Attenuation Coefficient versus Temperature.

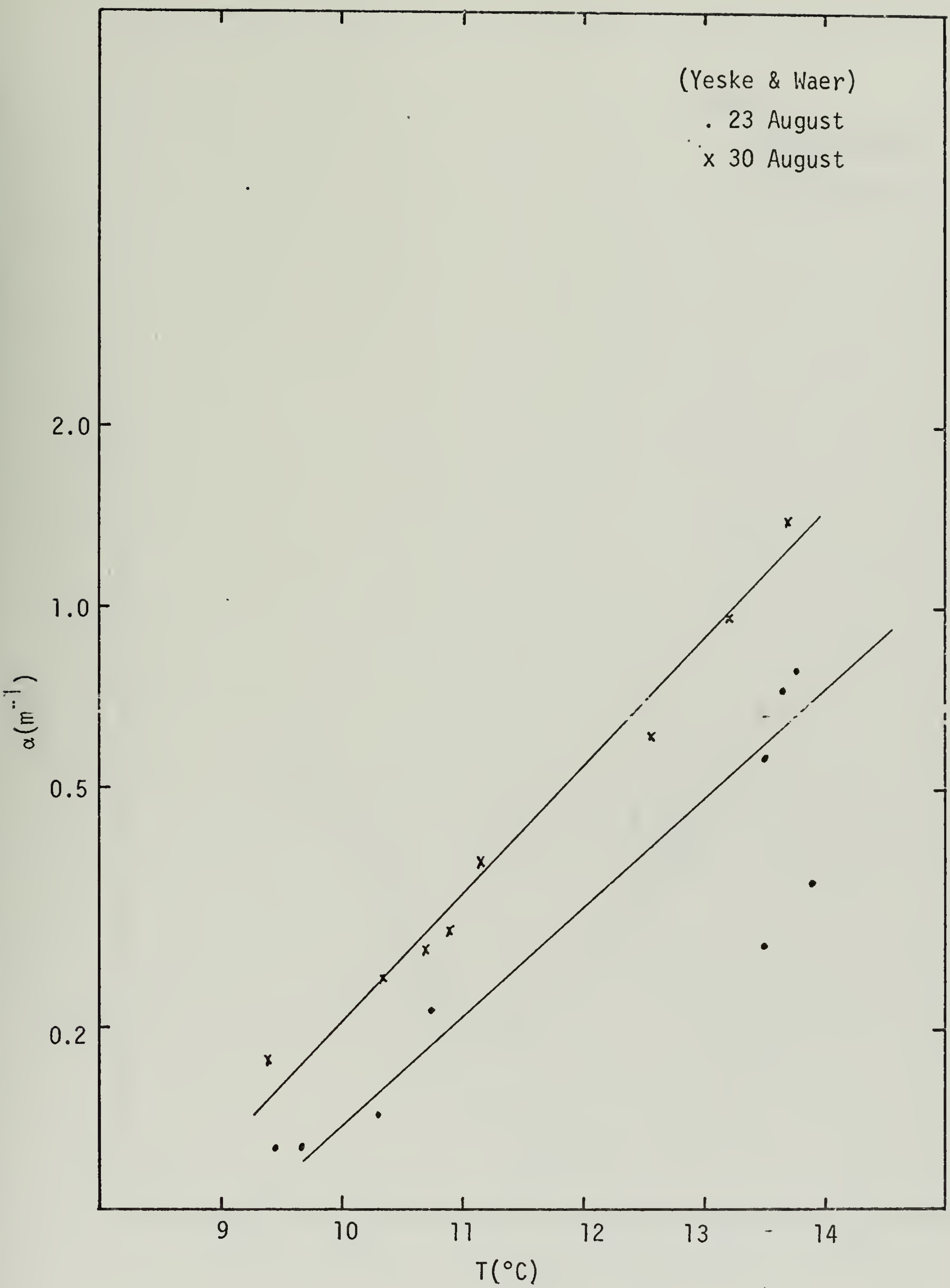


Figure 26. Attenuation Coefficient versus Temperature.

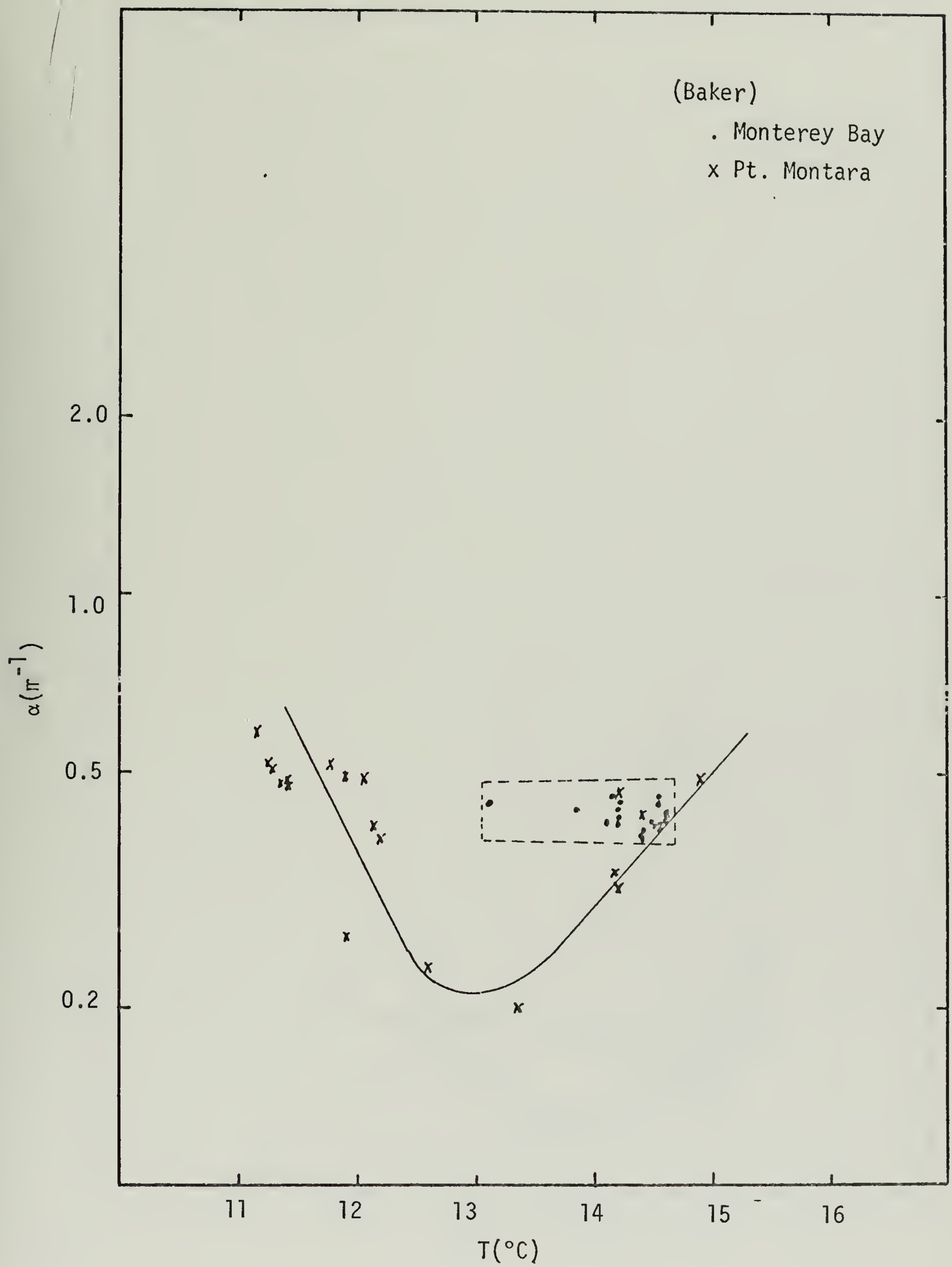


Figure 27. Attenuation Coefficient versus Temperature.

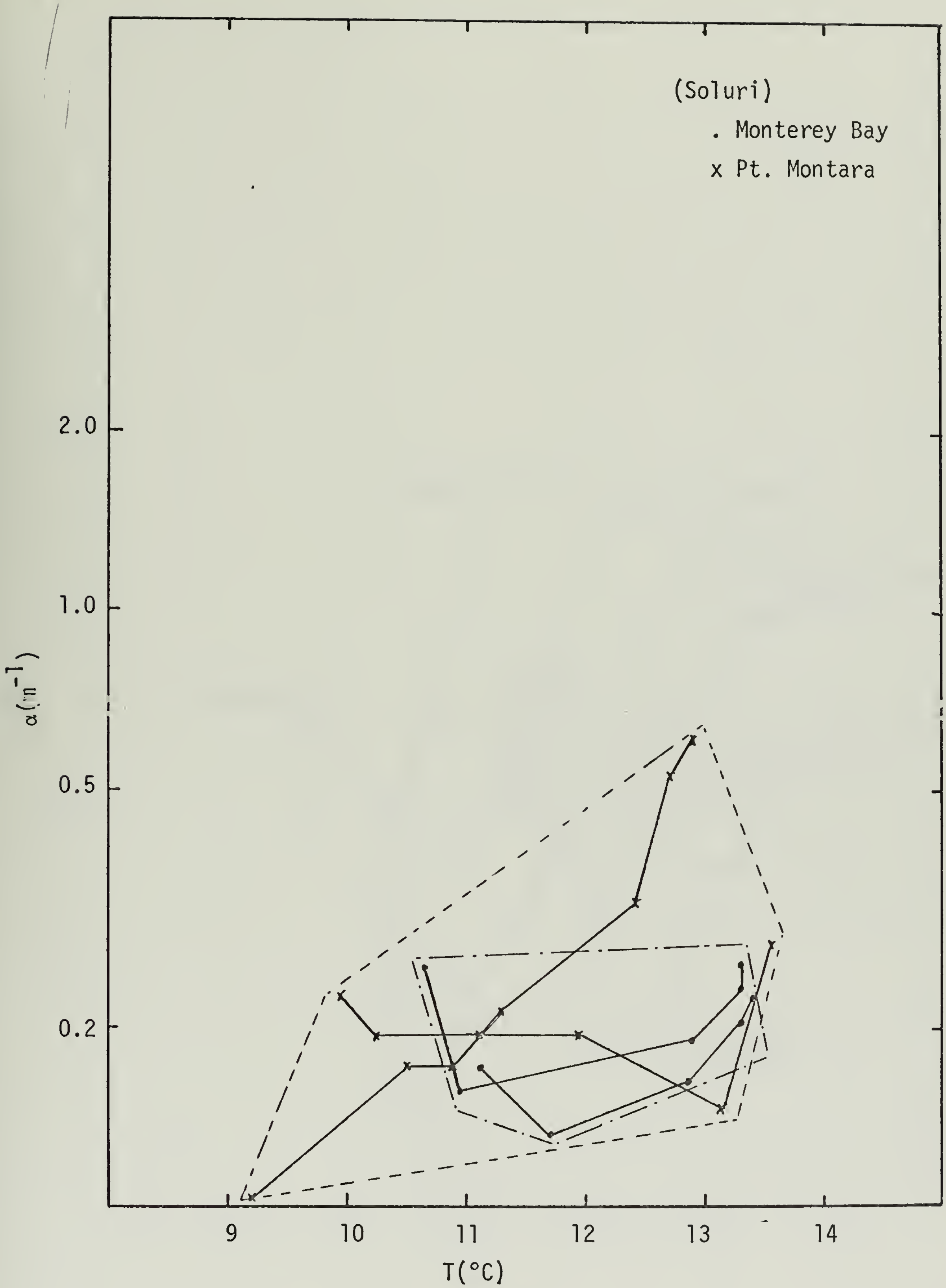


Figure 28. Attenuation Coefficient versus Temperature.

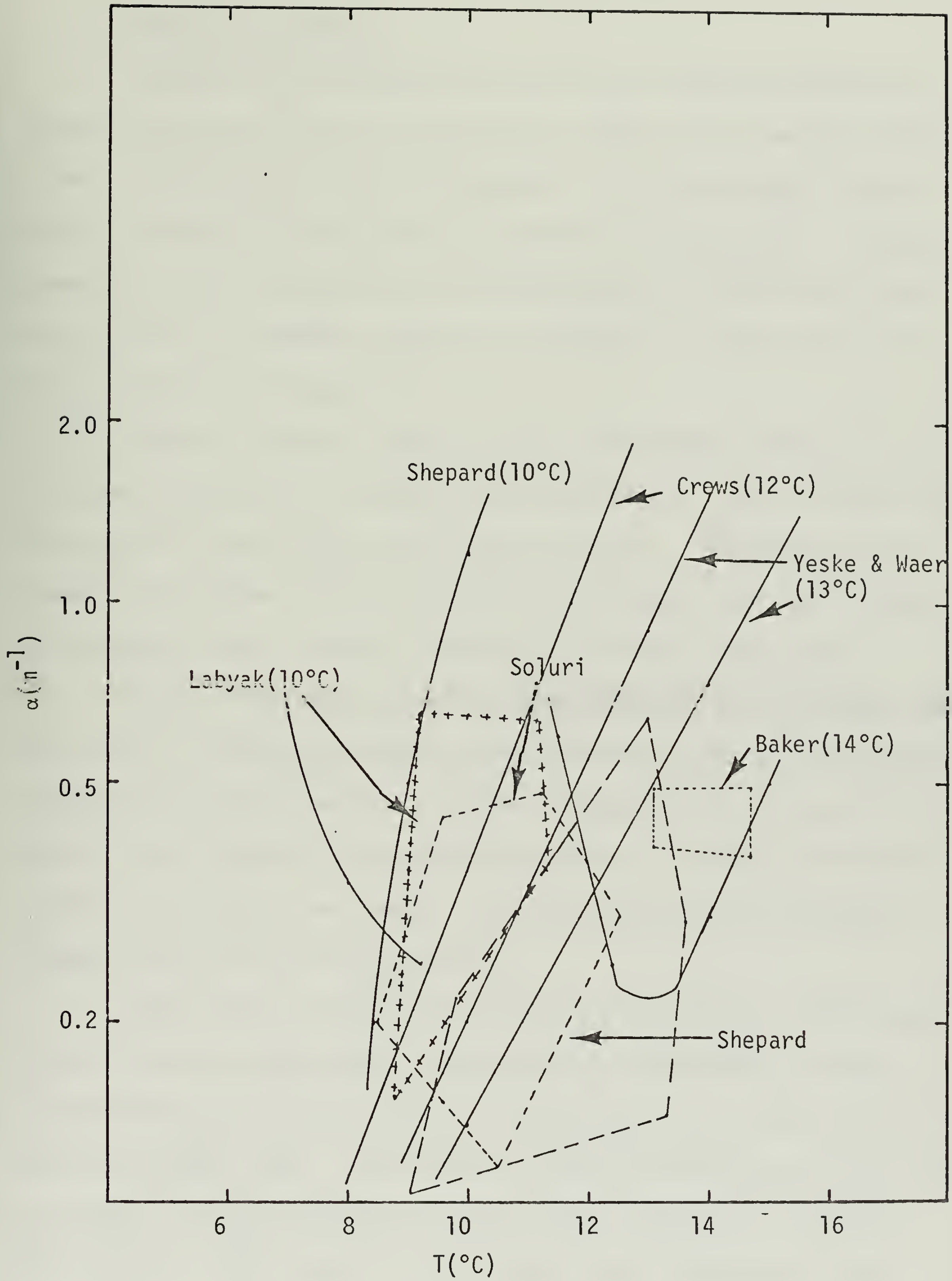


Figure 29. Attenuation Coefficient versus Temperature (Composite)

2. Chemical Parameters

Pytkowicz [17] observed the relationship between phosphate and oxygen concentrations off the Oregon Coast under varying seasonal conditions. Figure 30 is a plot of PO_4 against O_2 for the present station data. Pytkowicz's line for June is presented for comparison. Although there is a relation between these two parameters for the present data, this relation is different from that of Pytkowicz. Soluri's data are also presented for comparison.

Plots of log alpha against oxygen concentration (Figures 31 and 32) show relations for the present data and Shepard's data. On the other hand, Soluri's data (Figure 33) shows no relation. Presenting all of these plots together (Figure 34) shows that Shepard's and Crews' plots have similar slopes. Soluri's data was in a "clear" water area.

Plots of log alpha against phosphate content for the present data and Shepard's Monterey Bay station data (Figures 35 and 36) show a relation between these parameters. Shepard's Montara Point data as well as Soluri's data (Figure 37) show little relation. As before, for "clear" water little relation was found. Figure 38 presents the relationship between data for the various stations.

Figure 39 is a plot of log alpha against salinity. There appears to be a relation between these two parameters at the present station. Figure 40 shows a relation between these parameters for Yeske and Waer's data of 30 August 1969. The similarity between these curves and the curves of Figures 18 and 19 reflect the effect that salinity has on density. Both Shepard's data (Figure 41) and Soluri's data (Figure 42) show a relation between log alpha and salinity. As in previous comparisons, data obtained from "clear" water (Figures 41 and 43) tend to group rather than show any real relation. Figure 44 presents all of these plots together.

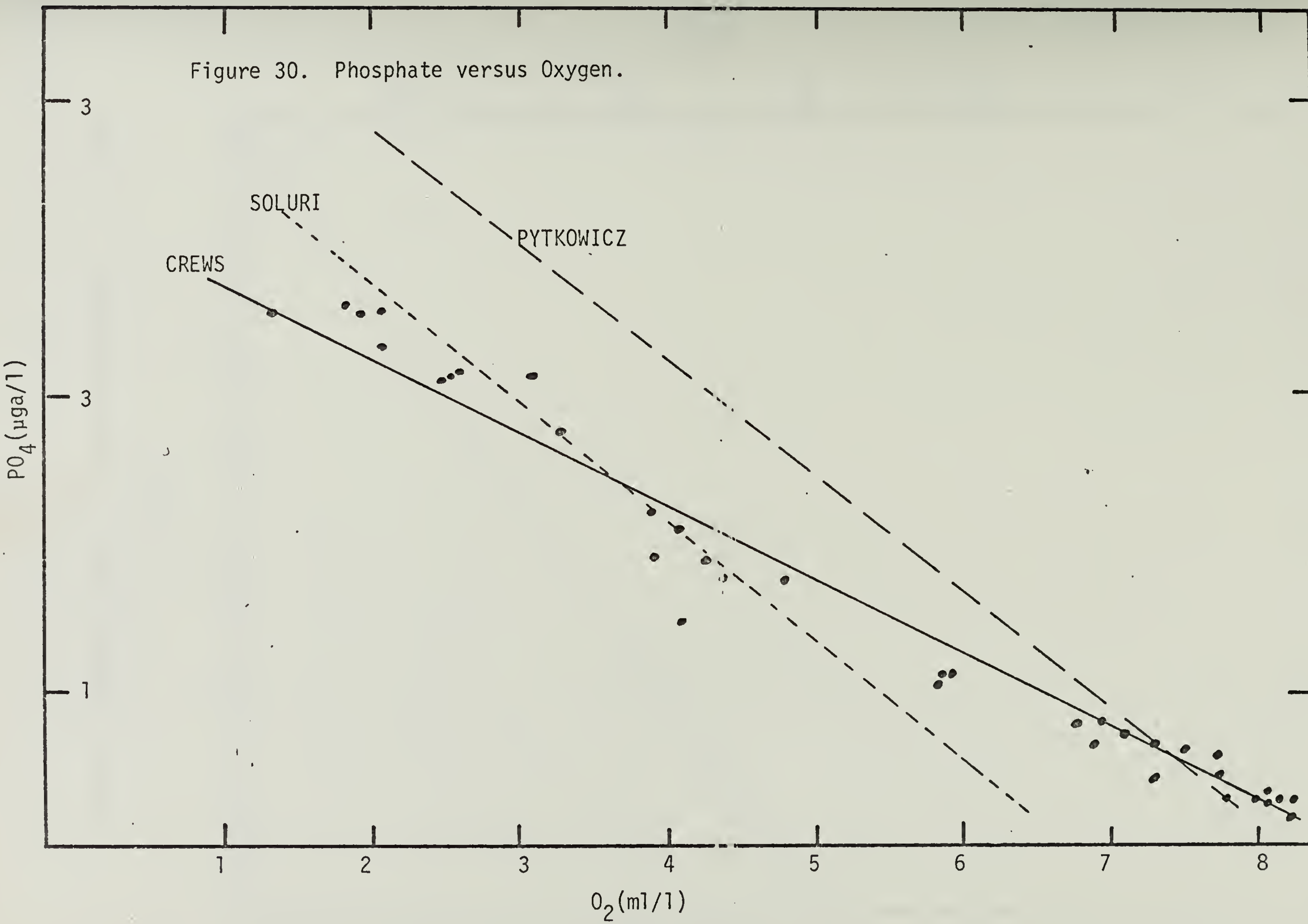


Figure 30. Phosphate versus Oxygen.

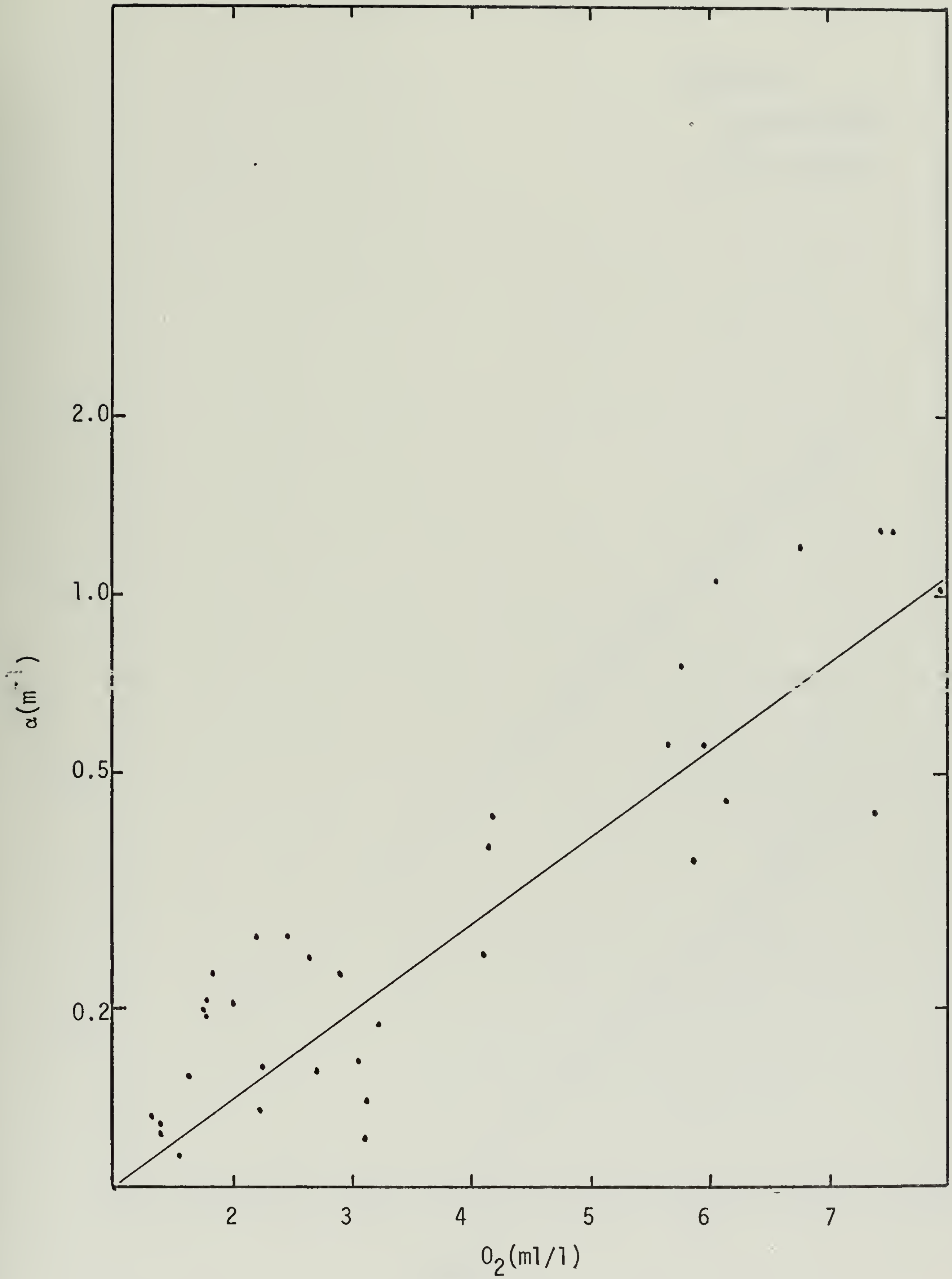


Figure 31. Attenuation Coefficient versus Oxygen. (Crews)

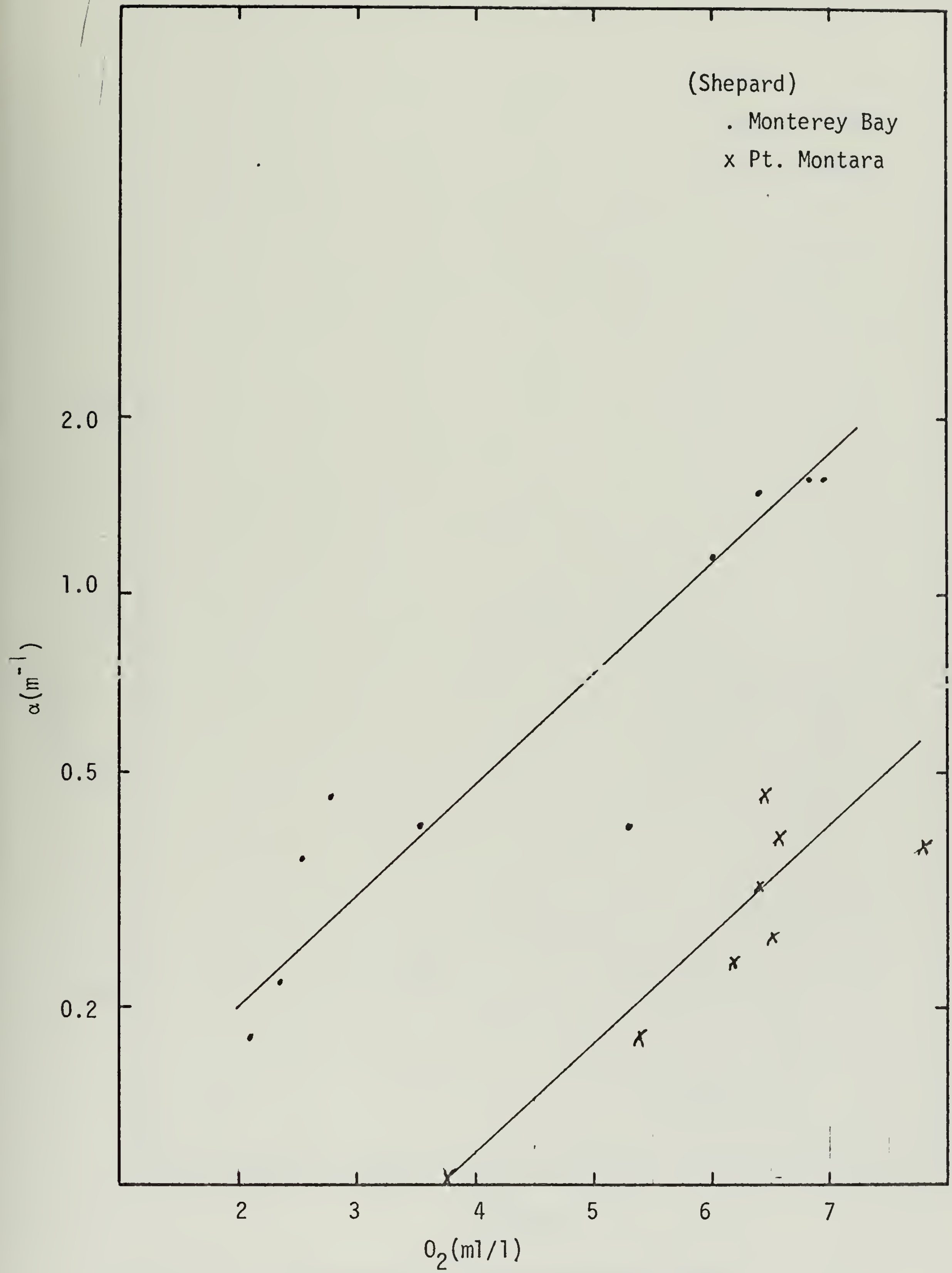


Figure 32. Attenuation Coefficient versus Oxygen.

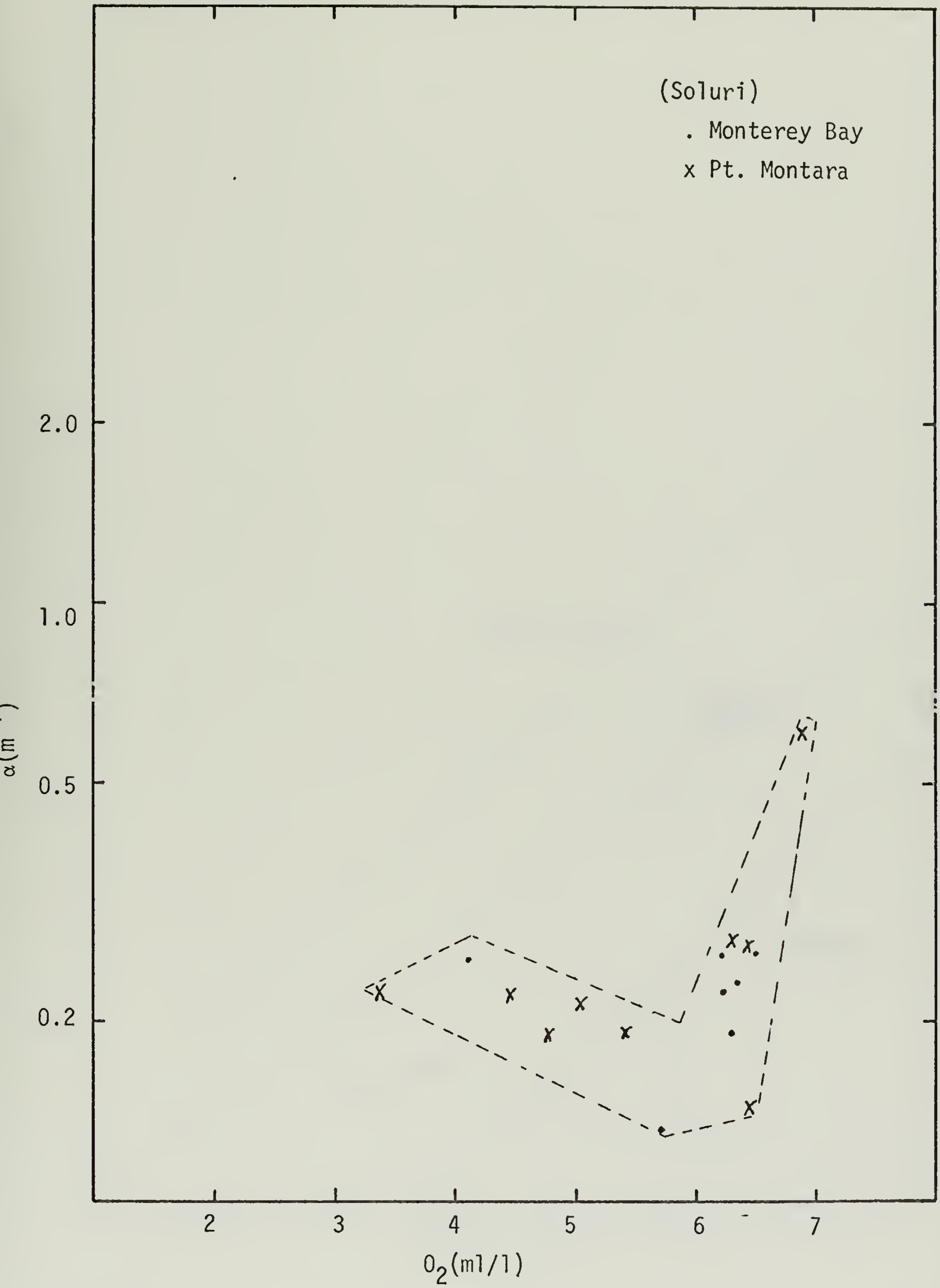


Figure 33. Attenuation Coefficient versus Oxygen.

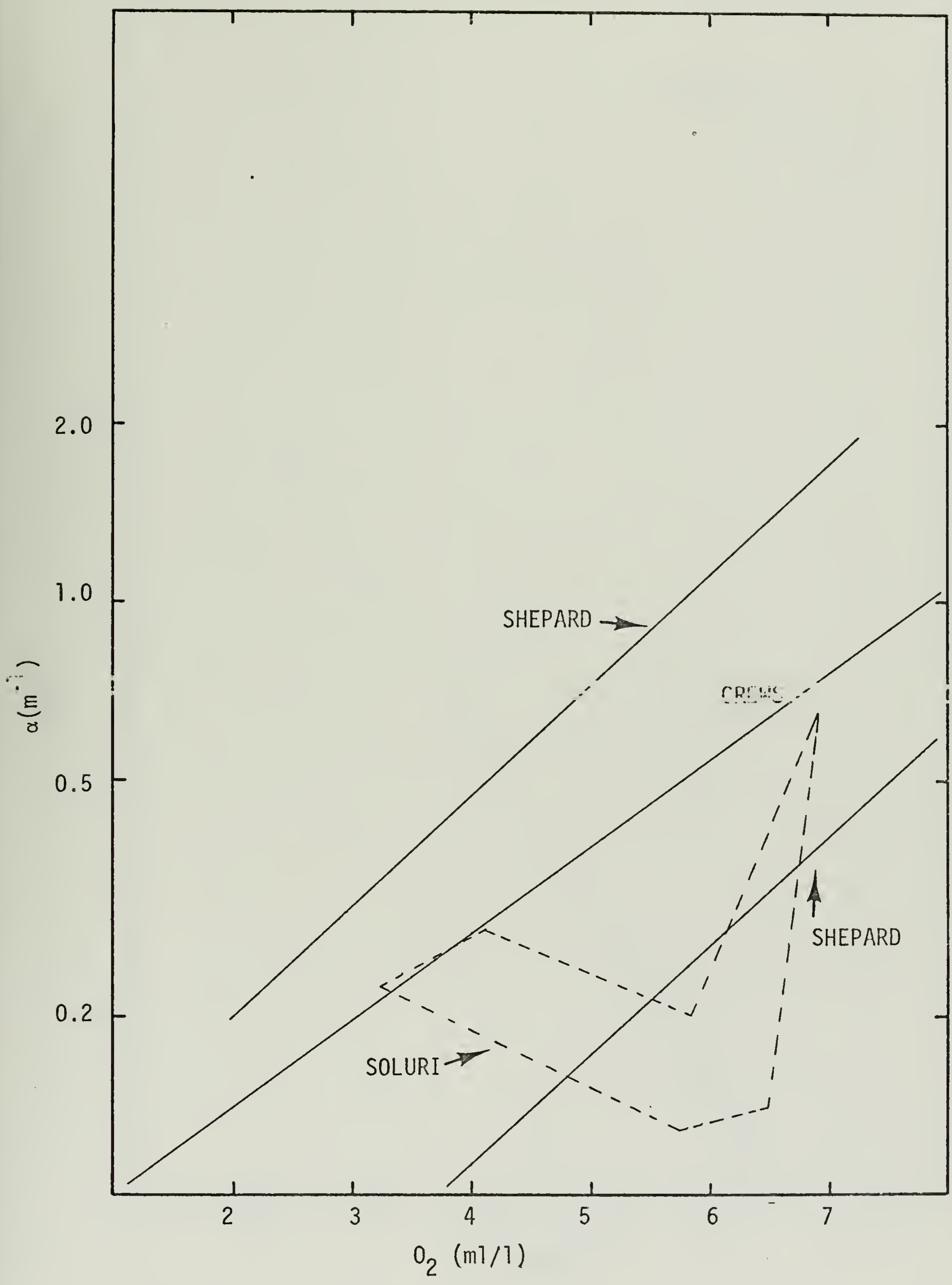


Figure 34. Attenuation Coefficient versus Oxygen (Composite)

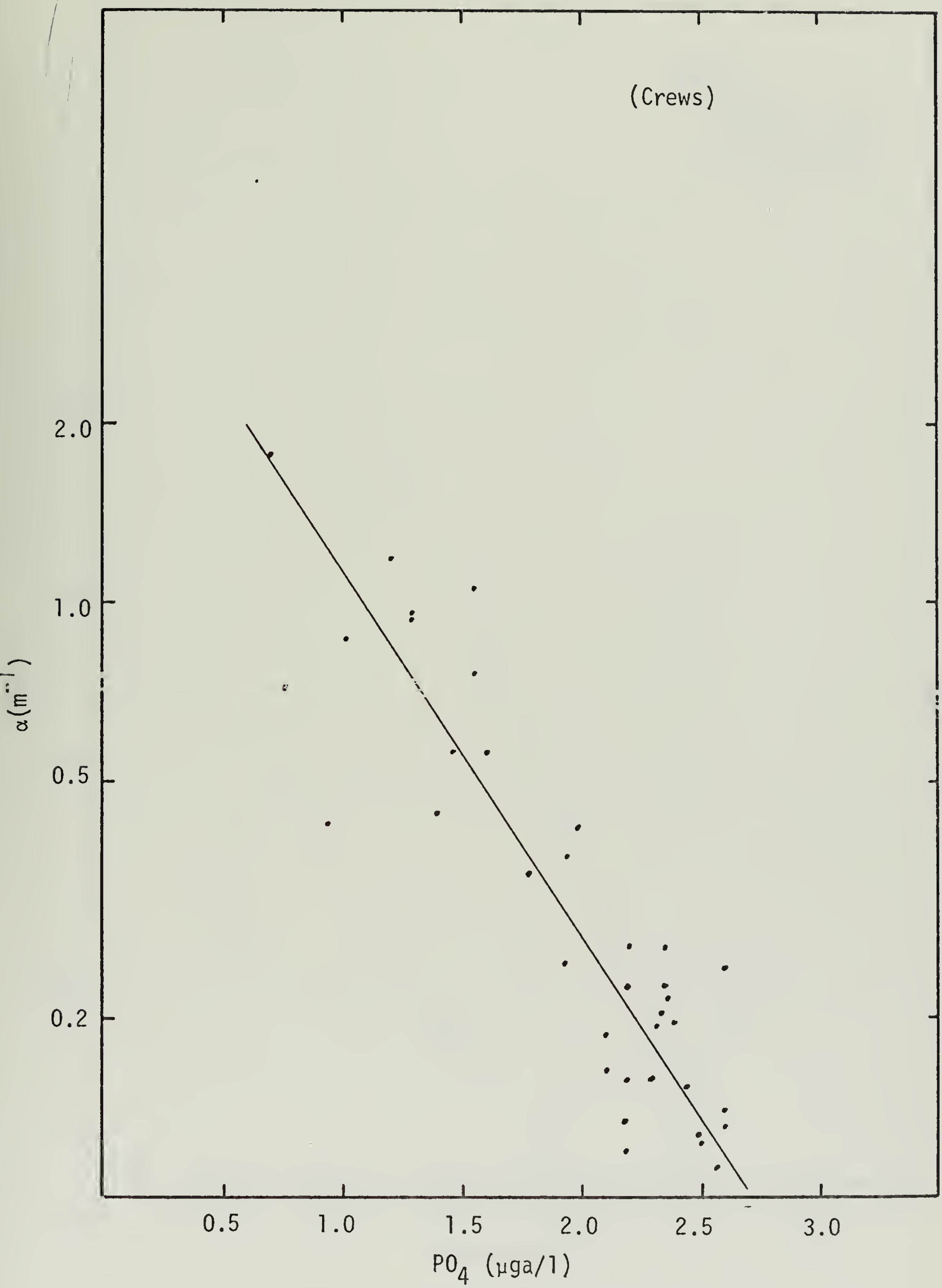


Figure 35. Attenuation Coefficient versus Phosphate.

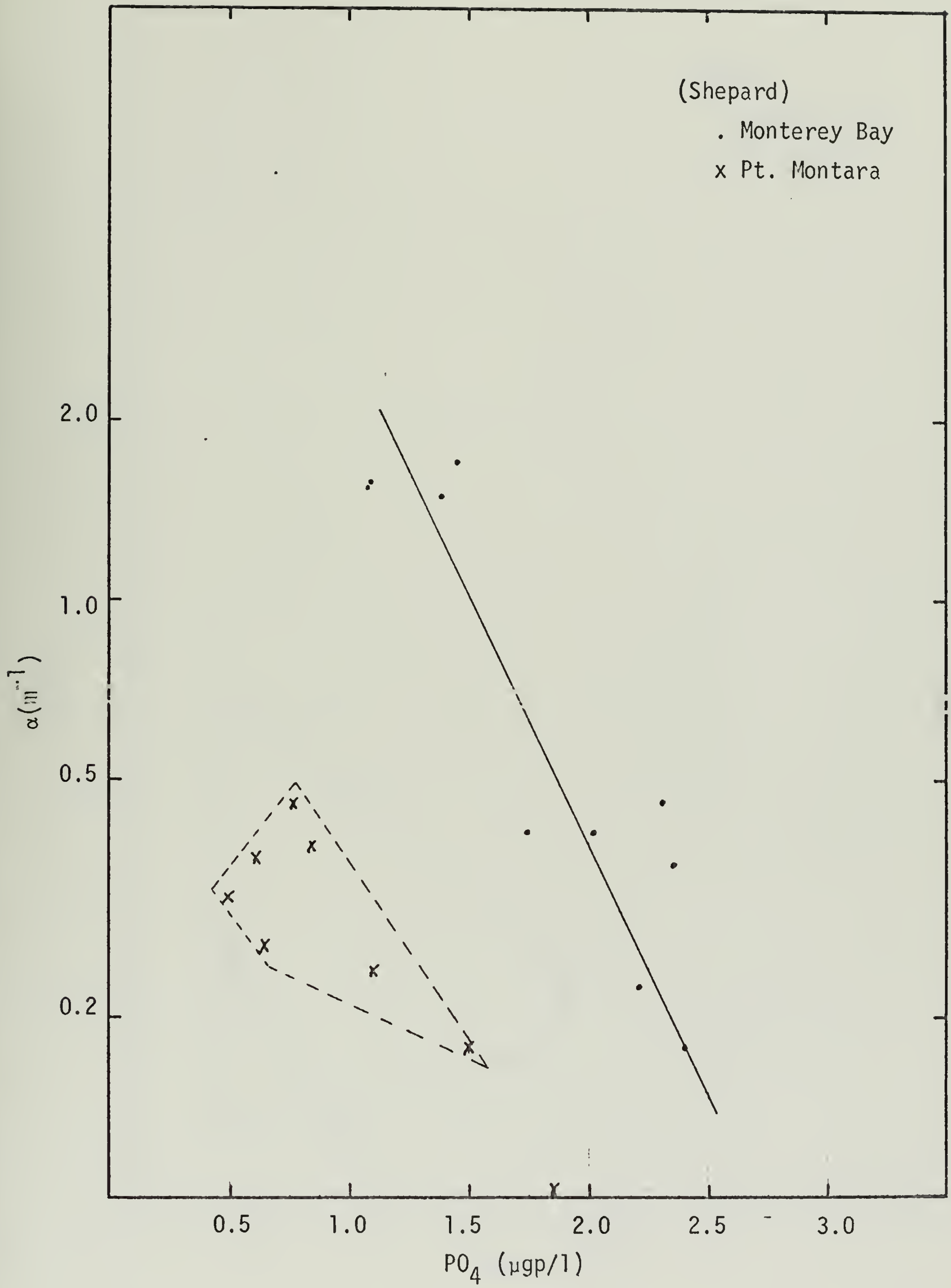


Figure 36. Attenuation Coefficient versus Phosphate.

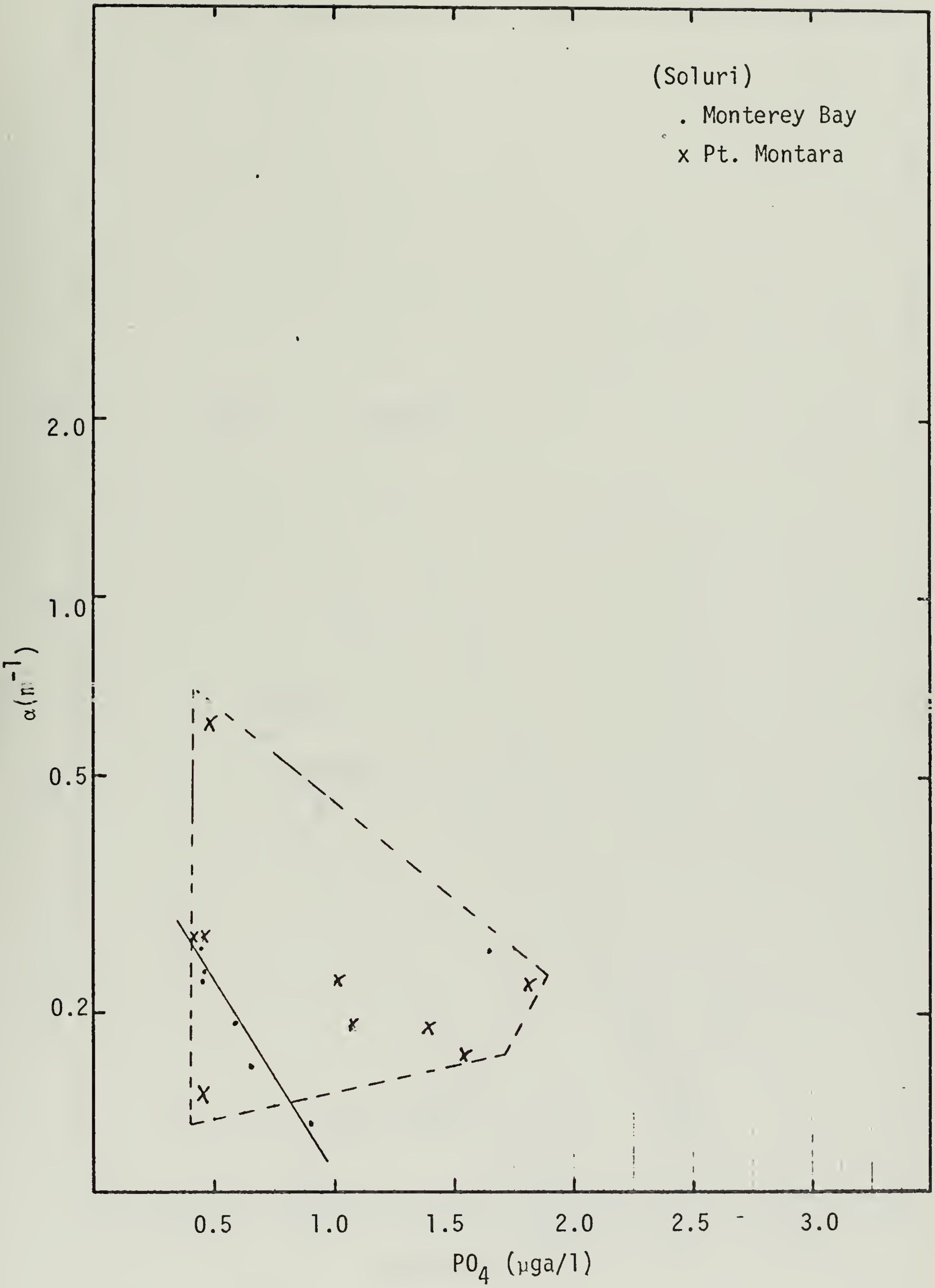


Figure 37. Attenuation Coefficients vs. Phosphate.

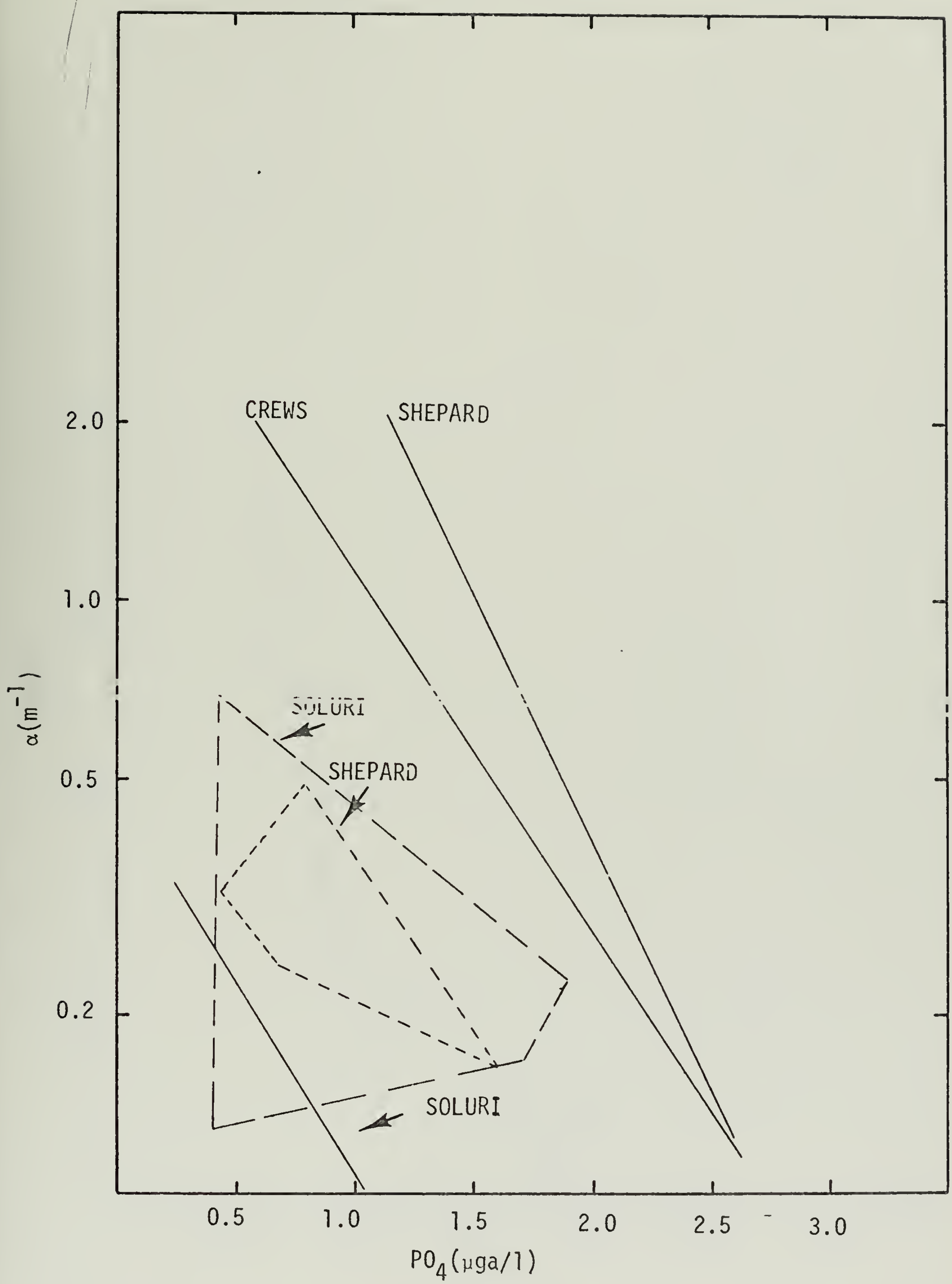


Figure 38. Attenuation Coefficient vs. Phosphase (Composite)

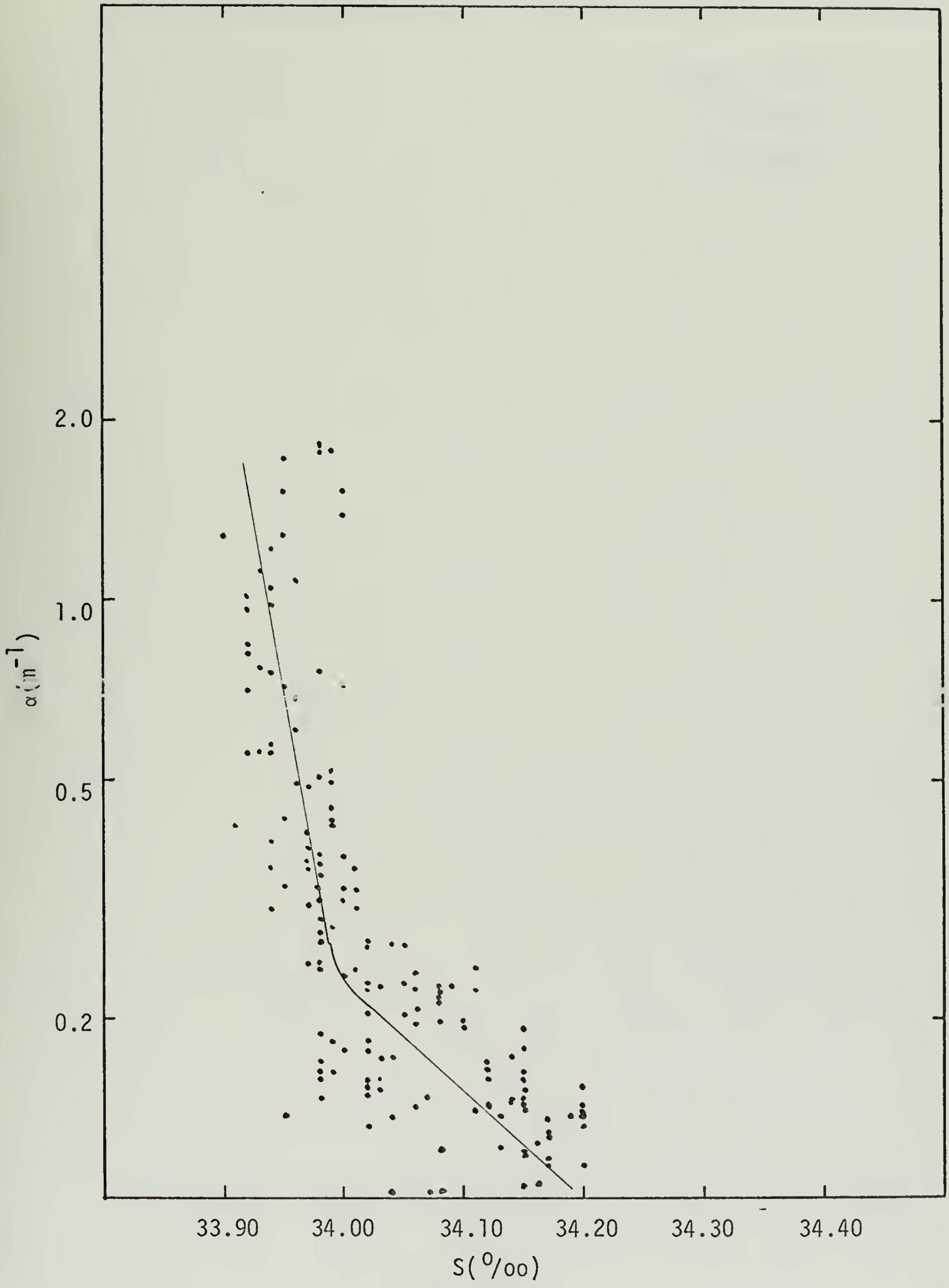


Figure 39. Attenuation Coefficient vs. Salinity (Crews).

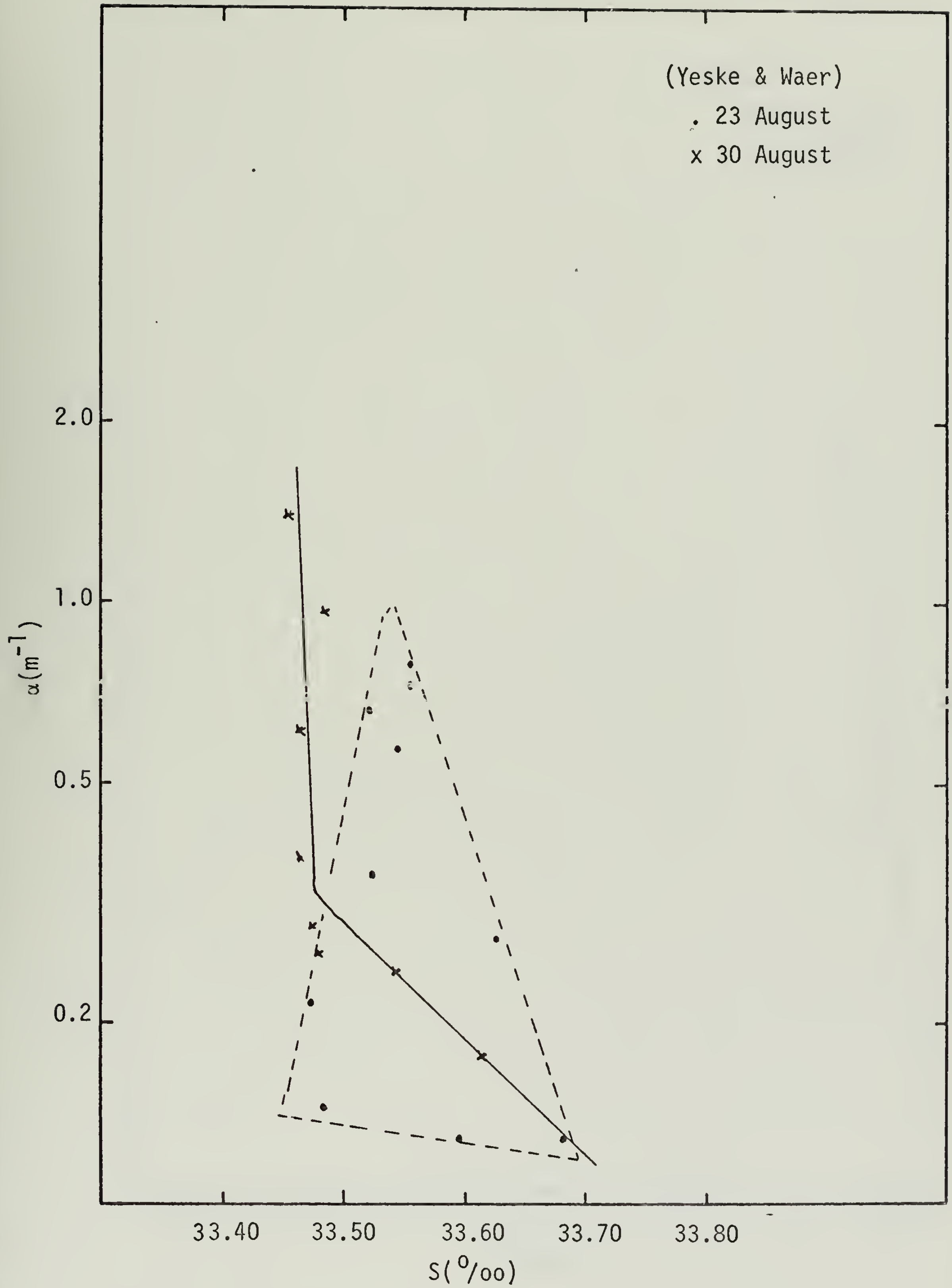


Figure 40. Attenuation Coefficient versus Salinity.

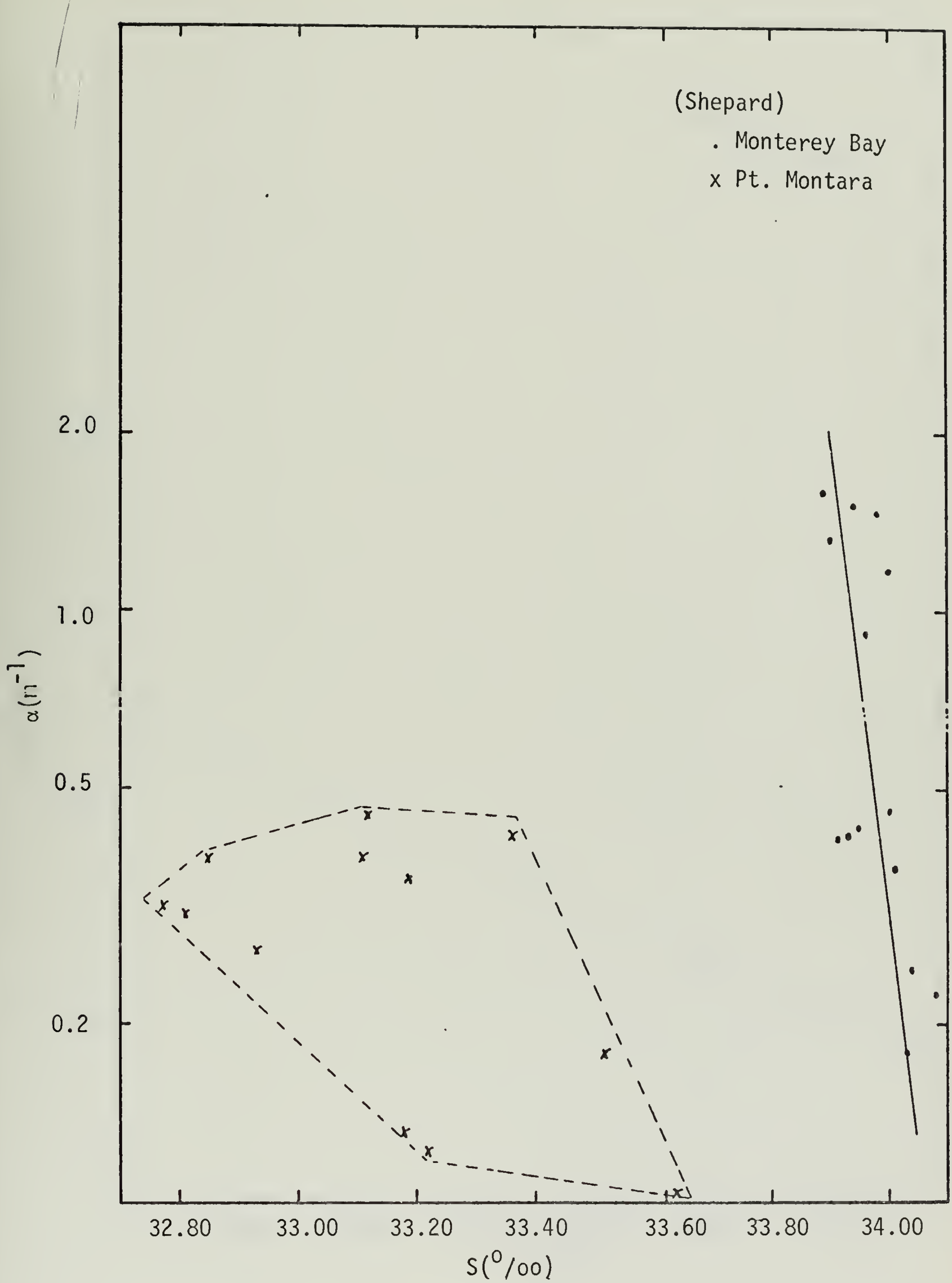


Figure 41. Attenuation Coefficient versus Salinity

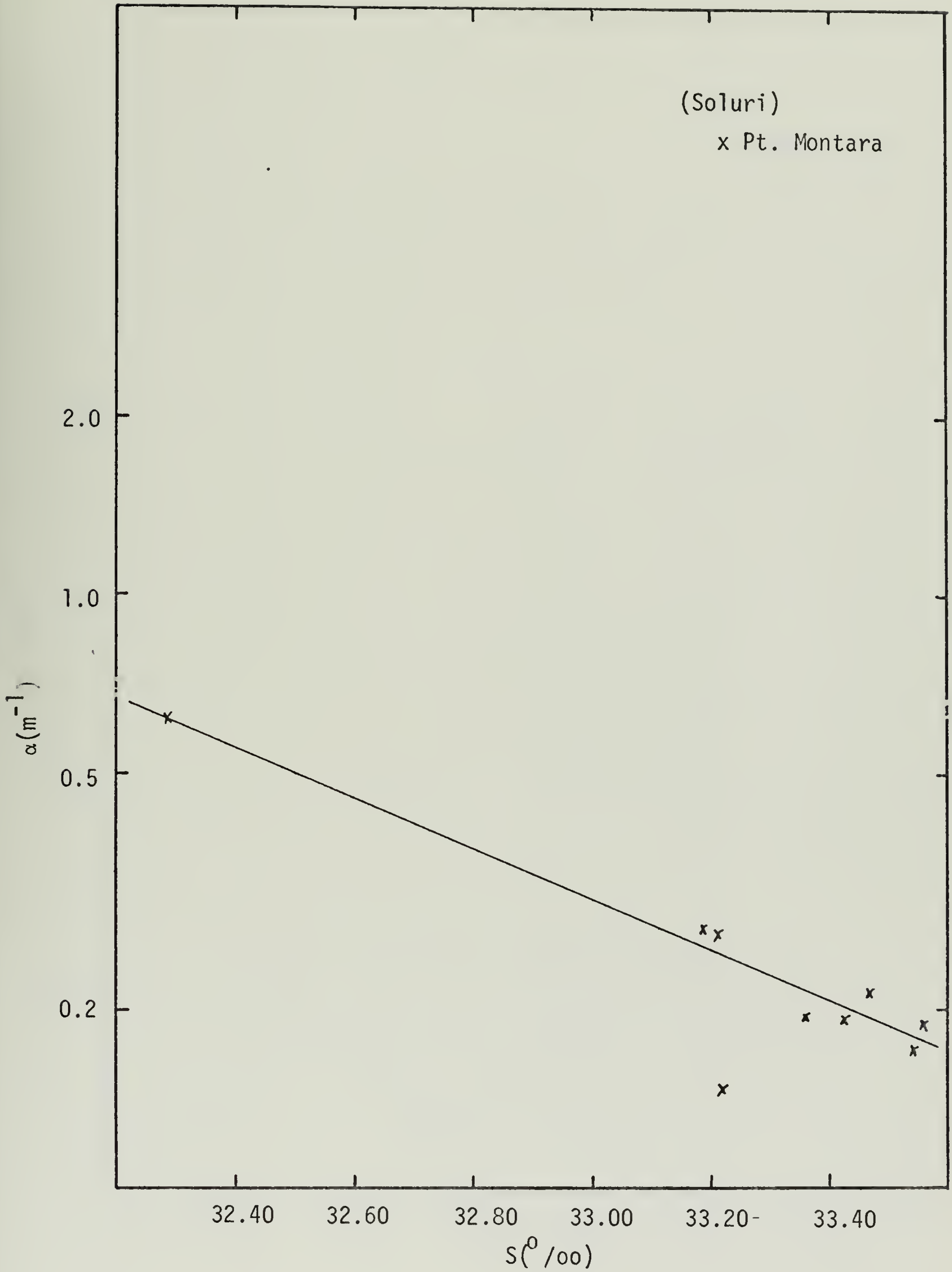


Figure 42. Attenuation Coefficient versus Salinity.

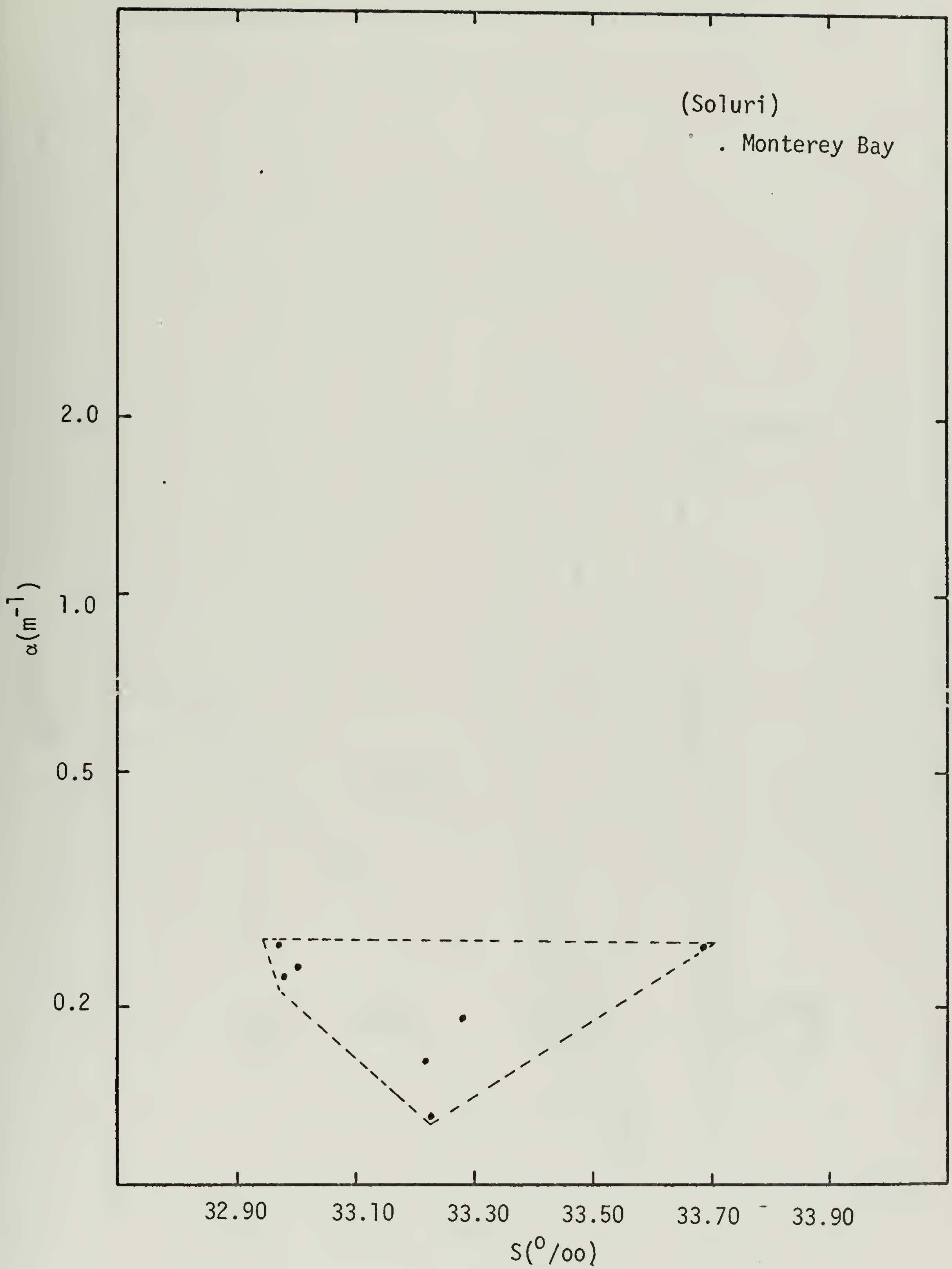


Figure 43. Attenuation Coefficient versus Salinity.

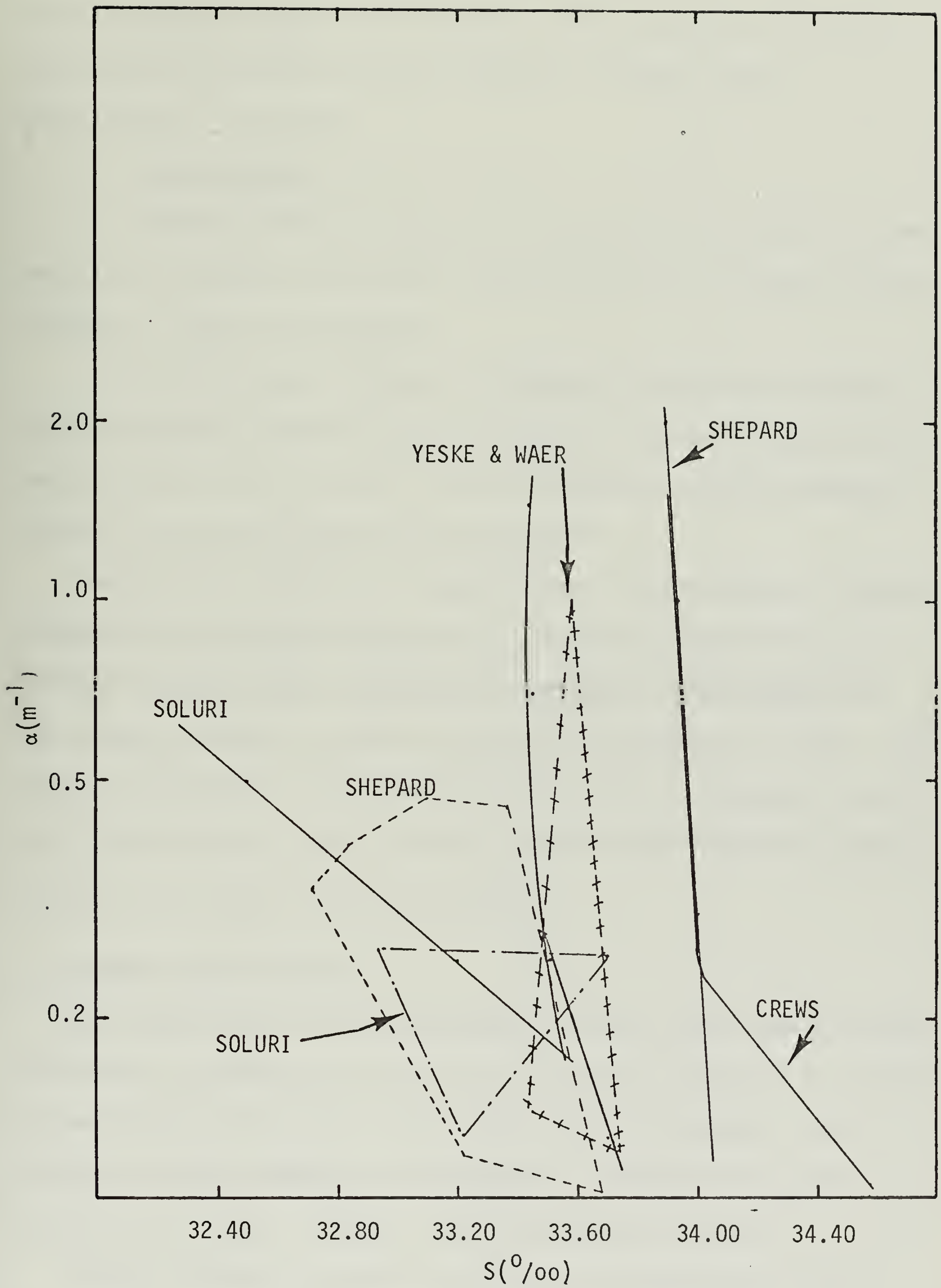


Figure 44. Attenuation Coefficient versus Salinity. (Composite)

As with density (Figure 22), the plots of log alpha against salinity show good relation under certain conditions, however, these relationships vary widely.

3. Time Dependence

Vertical profiles of oxygen and phosphate concentration, alpha, salinity, temperature, and density are presented for the entire 28 hour station in Figures 45 through 50.

Only gross approximations of temporal change can be obtained from the oxygen (Figure 45) and the phosphate (Figure 46) concentration profiles due to lack of data. While the phosphate isopleths remained stable, the oxygen isopleths varied vertically.

Comparing the isopleths of alpha (Figure 47) with those for salinity (Figure 48), temperature (Figure 49), and density (Figure 50) it is evident that the highest gradients of alpha occur in the pycnocline. The temporal changes in these isolines may be attributed to tidal fluctuations as suggested by Yeske and Waer [26] as well as biological causes and internal waves. Again, in order to get high resolutions of temporal change, more frequent casts must be made.

C. SUMMARY AND DISCUSSION

While particulate matter suspended in a water column greatly affects the amount of scattering of the light, the density structure of the water column affects the particle distribution within the column. Since density is highly dependent on temperature, the latter is a good parameter with which to relate light attenuation in the sea.

During an upwelling period a majority of the particulate matter suspended in the water is planktonic. Chemical parameters such as oxygen and phosphate concentrations will be affected by the amount of

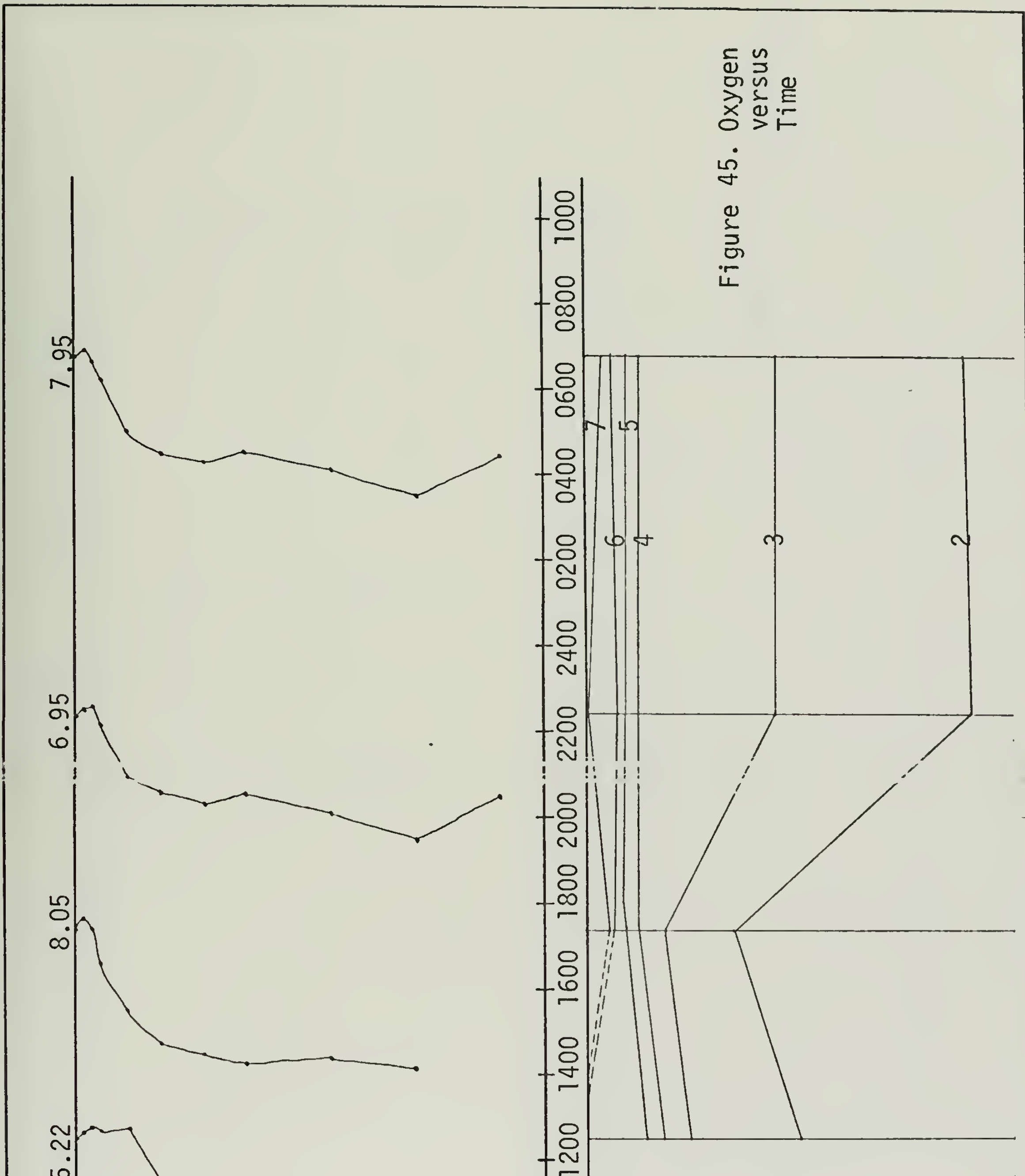


Figure 45. Oxygen versus Time

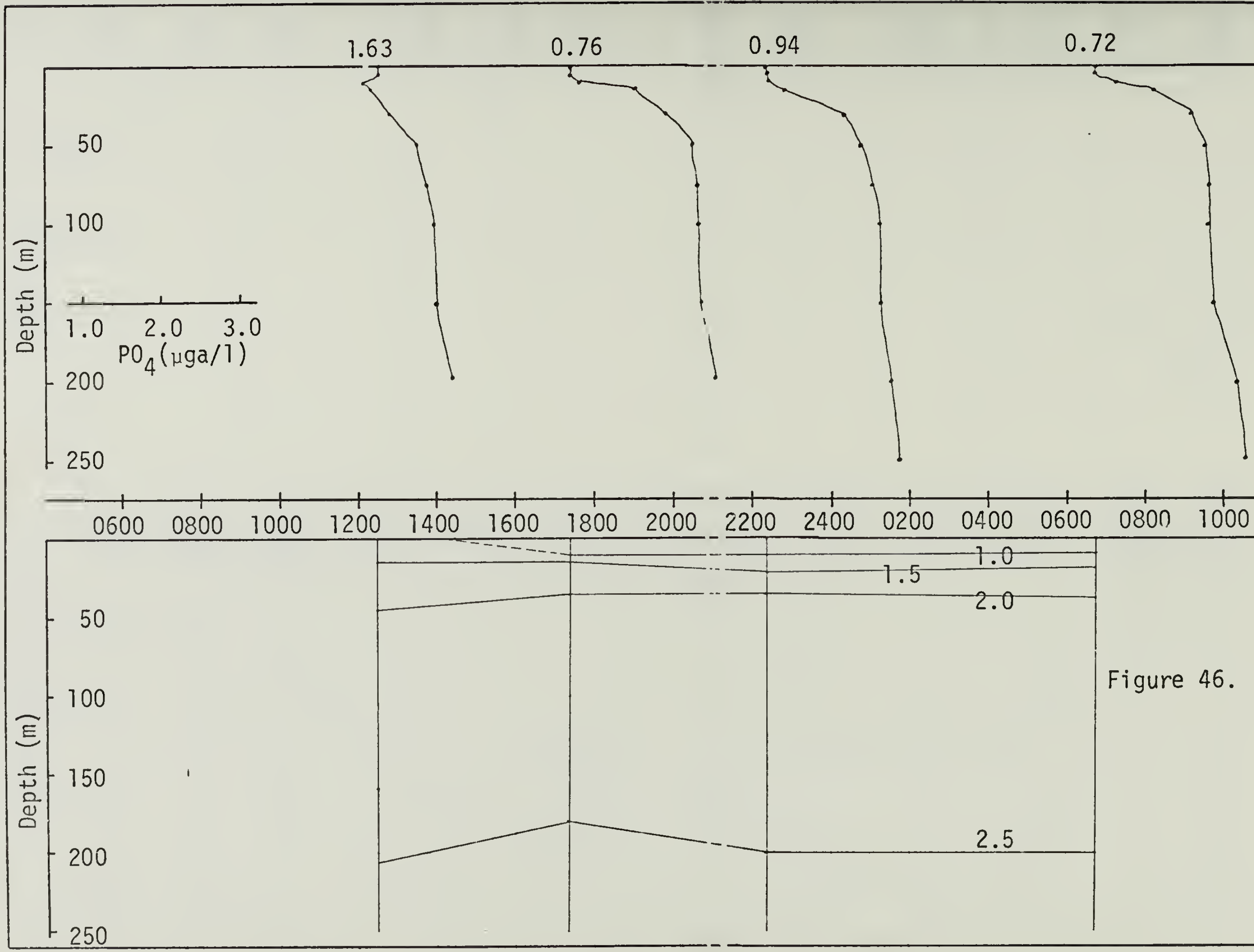


Figure 46. Phosphate versus Time

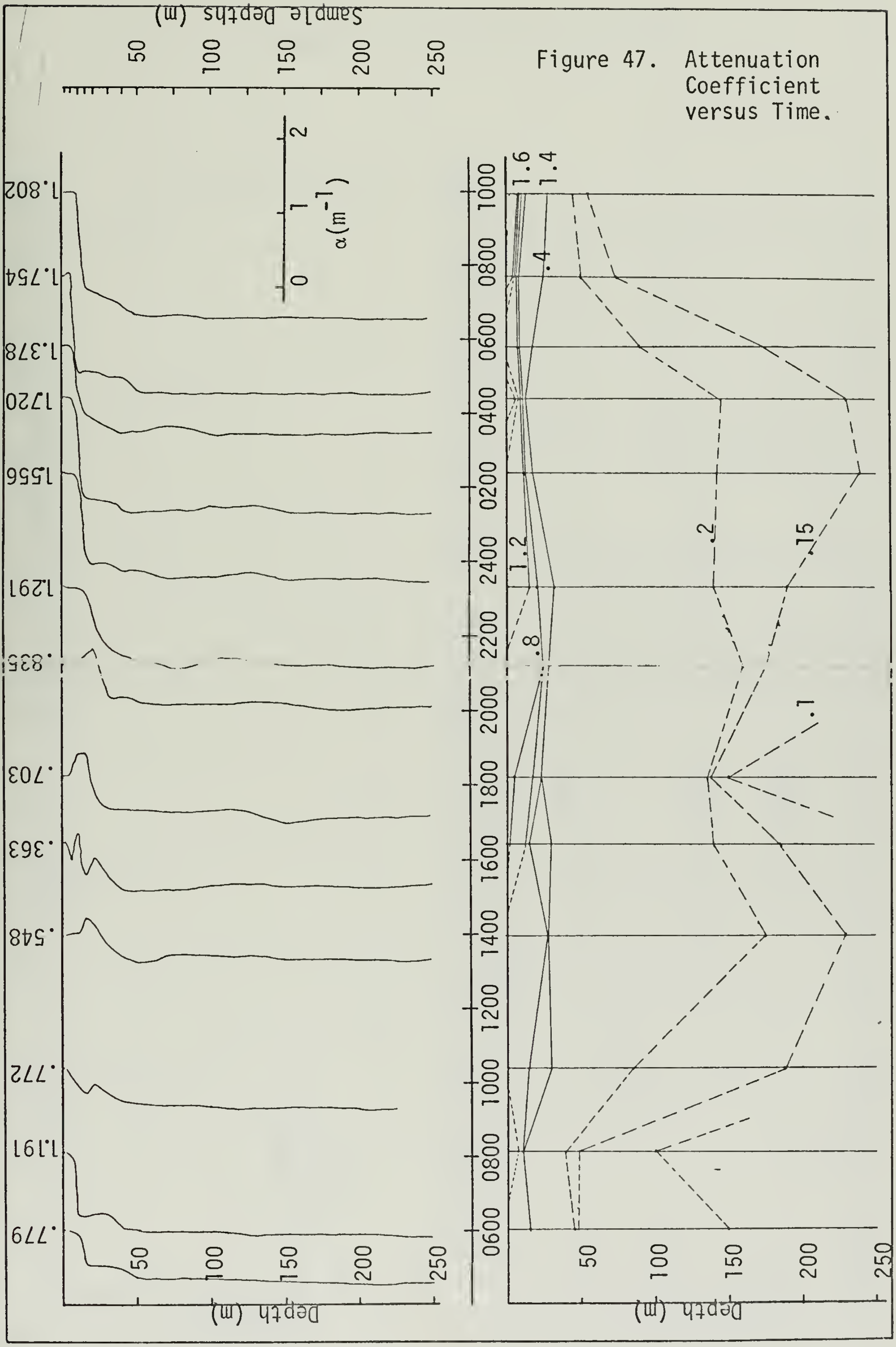


Figure 47. Attenuation Coefficient versus Time.

Figure 48. Salinity versus Time.

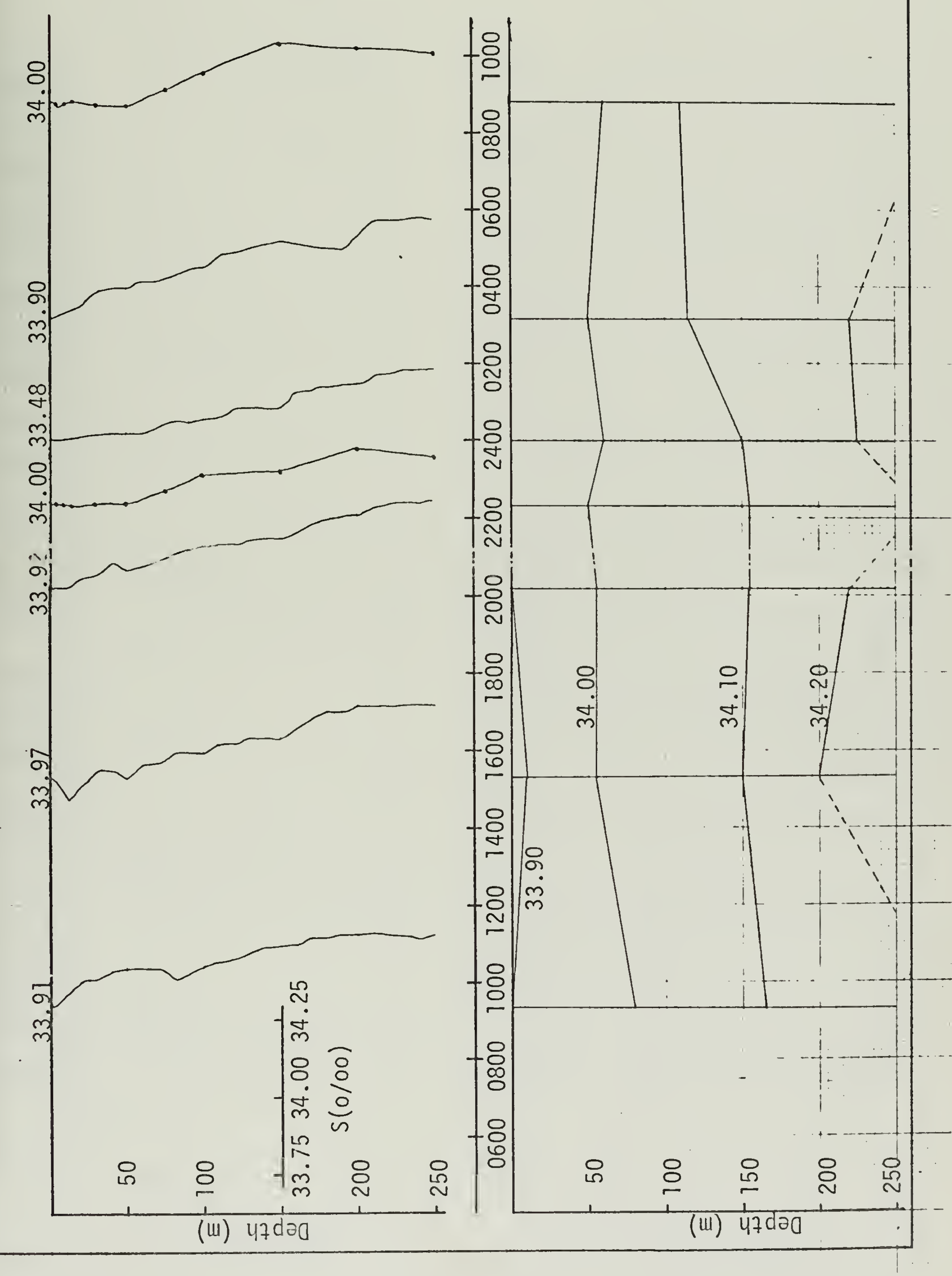
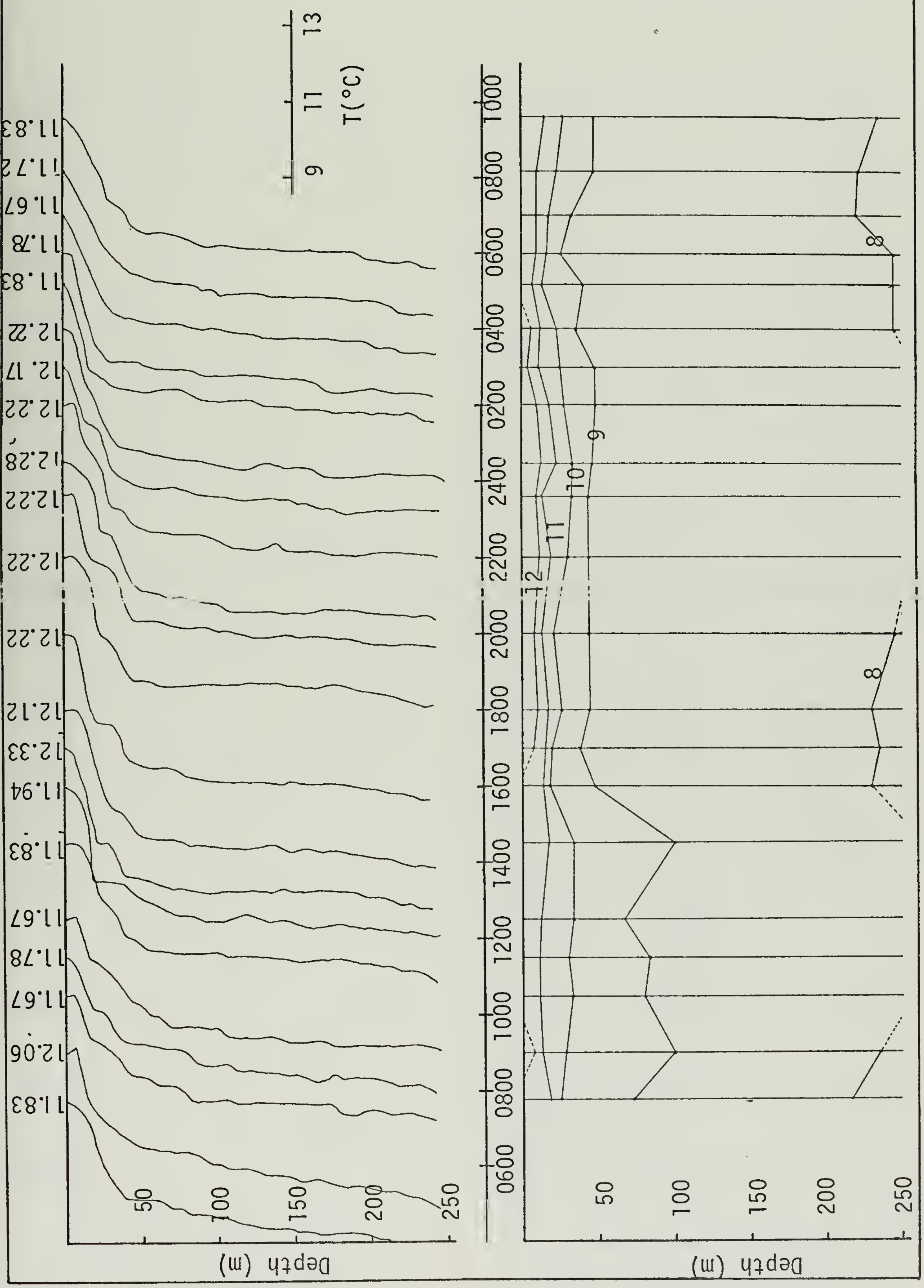


Figure 49. Temperature versus Time.



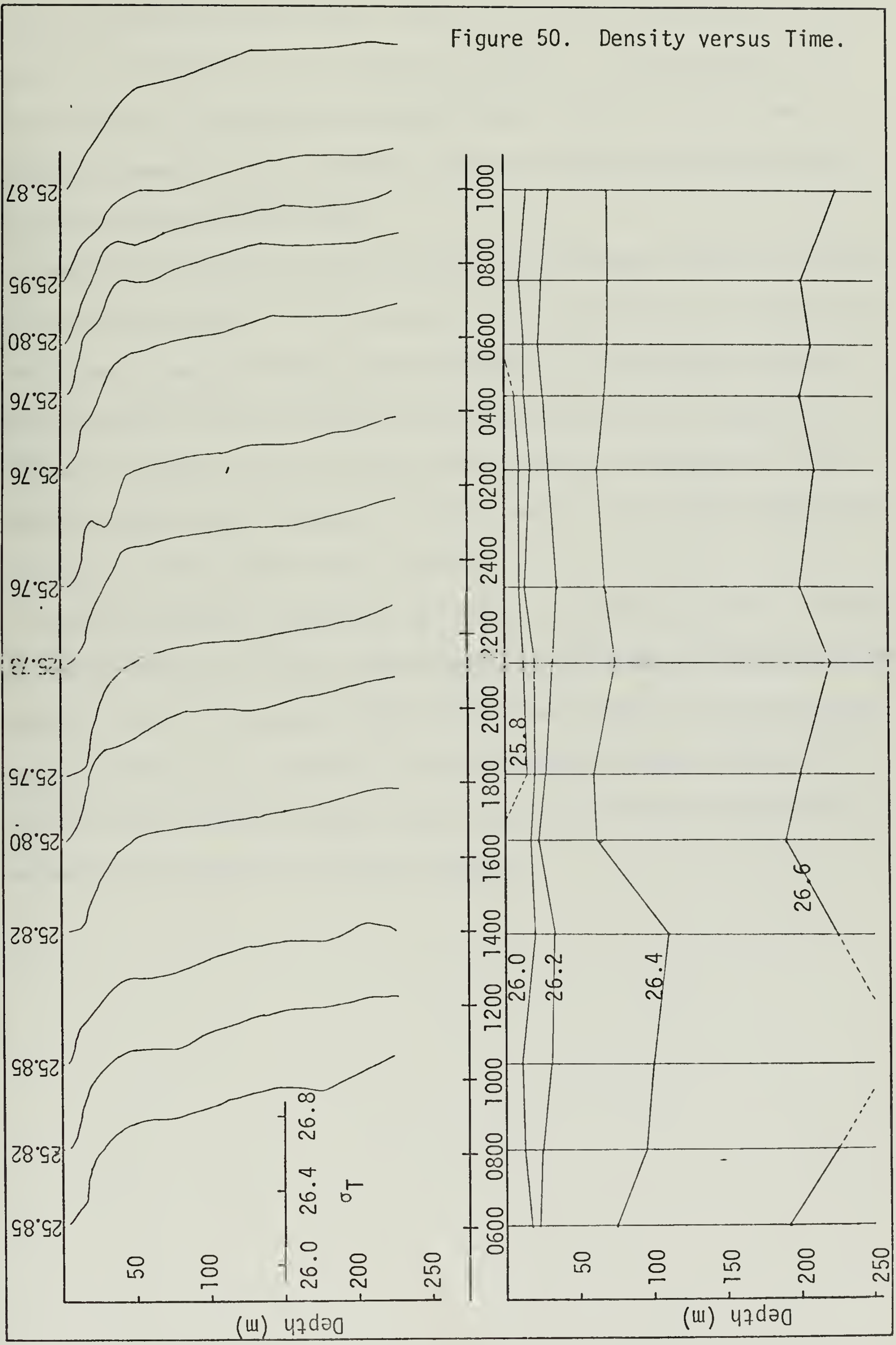


Figure 50. Density versus Time.

such particulate matter present, which will reflect the amount of productivity. Salinity, as it relates to density, also determines the distribution of suspended particulate matter. All of these oceanographic parameters can be related to light attenuation, in particular to the scattering coefficient.

One would like to be able to predict the inherent optical properties of a given water mass. From the qualitative approach of this study, it can be seen that prediction may be possible. In particular, the relative positions of the various plots of log alpha against temperature (Figure 29) appear to be related to the surface temperature. As the surface temperature increases, the plots move to the right (temperature increases to the right in this figure).

In all cases when the water was either "relatively clear" or "clear", it was difficult to relate light attenuation with any of the other parameters. This is reasonable since "clear" water means less particulate matter, thus lower scattering. It is encouraging that, although the various data clustered together under these conditions, the groupings in general were located as one would expect.

IV. CONCLUSIONS

The vertical distributions of particulate matter, density, salinity, temperature, oxygen and phosphate concentrations, and light attenuation coefficient are dependent on both the seasonal conditions and geographical location.

A good relation between the light attenuation coefficient and particulate matter concentrations was found. The largest concentrations were found in the upper 10 - 15 m, where the largest light attenuation also occurred. The largest attenuation gradient occurred in the pycnocline. An apparent linear relation was found between the attenuation coefficient and the cumulative projected cross-sectional area of the particles.

A good relation was found between log attenuation coefficient and temperature. Fair relation was found between log attenuation coefficient and salinity and density. Fair relation was found between log attenuation coefficient and the oxygen and phosphate concentrations.

V. SUGGESTIONS FOR FUTURE RESEARCH

More stations should be occupied for periods of at least 24 hours to determine the inherent optical properties under differing seasonal conditions and at various locations.

A computer analysis of the relatively large amount of data already available should be conducted to determine numerically the correlations between the various oceanographic parameters.

The beam transmissometer should be fitted with a variable interference filter to study the spectral dependence of the beam attenuation coefficient.

Detailed studies should be conducted to identify the various suspended particles to be found and their respective roles with regard to the optical characteristics of the water column.

APPENDIX A - DATA TABLES

Table I - Summary of Casts

TIME	CAST			
	HYDRO	S/T/D/SV	α	XBT
16 June 1971				
0600				X
0603			X	
0630				X
0742				X
0800				X
0808			X	
0900				X
0918		X		
1000				X
1025			X	
1030				X
1130				X
1230				X
1235	X			
1355			X	
1430				X
1508		X		
1600				X
1627			X	
1700				X
1723	X			
1800				X
1811			X	
1959		X		
2000				X
2113			X	
2200				X
2220	X			
2317			X	
2340				X
2354		X		
17 June 1971				
0030				X
0200				X
0226			X	
0300		X		X
0400				X
0424			X	
0512				X
0548			X	
0600				X
0700				X
0731			X	
0810				X
0845	X			
0934				X
0959			X	

Table IIa - HYDROGRAPHIC CAST DATA

Time:

Down 161215 June 1971

Up 161300 June 1971

Cast 161235 June 1971

Depth (meters)	Salinity ($^{o}/oo$)	O_2 (ml/l)	PO_4 (μga/l)
0	- - -	5.22	1.63
5	- - -	5.65	1.61
10	- - -	5.98	1.47
15	33.891	5.76	1.55
30	33.874	5.88	1.79
50	33.950	3.05	2.10
75	33.976	2.49	2.20
100	33.500	2.20	2.35
150	33.647	1.89	2.32
200	33.477	1.64	2.44
250	- - -	- -	- -

Table IIb - HYDROGRAPHIC CAST DATA

Time:

Down 161713 June 1971

Up 161732 June 1971

Cast 161725 June 1971

Depth (meters)	Salinity ($^{0}/oo$)	O_2 (ml/l)	PO_4 (μga/l)
0	33.191	8.05	0.76
5	33.430	8.69	0.76
10	33.754	7.99	0.87
15	33.574	6.06	1.55
30	33.906	4.10	1.94
50	33.397	2.65	2.30
75	33.581	2.01	2.33
100	33.437	1.78	2.36
150	33.808	1.88	2.36
200	34.038	1.54	2.56
250	- - -	- -	- -

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]

Table IIc - HYDROGRAPHIC CAST DATA

TIME:

Down 162200 June 1971

Up 162243 June 1971

Cast 162220 June 1971

Depth (meters)	Salinity ($^{o}/oo$)	O_2 (ml/l)	PO_4 (µga/l)
0	33.996	6.95	0.94
5	33.999	7.44	0.94
10	33.997	7.53	0.96
15	33.990	6.78	1.18
30	33.991	4.19	1.99
50	34.000	2.90	2.17
75	34.035	2.27	2.28
100	34.082	1.82	2.35
150	34.098	1.75	2.39
200	34.172	1.40	2.50
250	34.132	1.32	2.61

Table IId - HYDROGRAPHIC CAST DATA

Time:

Down 170830 June 1971

Up 170904 June 1971

Cast 170845 June 1971

Depth (meters)	Salinity (‰)	O_2 (ml/l)	PO_4 (μga/l)
0	34.001	7.95	0.72
5	33.985	8.19	0.70
10	33.995	7.41	0.94
15	33.996	6.12	1.40
30	33.983	4.13	1.93
50	33.977	3.24	2.10
75	34.087	3.12	2.18
150	34.178	2.24	2.18
200	- - -	1.42	2.49
250	34.140	3.11	2.60

Table III - S/T/D/SV REFERENCE DATA

Salinity:

Mode - 3
Interval - 33.0 to 35.0 ppt
Accuracy - ± 0.02 ppt

Temperature:

Mode - 3
Interval - +6 to +11 °C
Mode - 4
Interval - +10 to +15 °C
Accuracy - ± 0.02 °C

Sound Velocity:

Mode - 3
Interval - 1480 to 1530 m/sec
Accuracy - ± 0.3 m/sec

Depth:

Accuracy - 0 to 500 m ± 4 m
500 to 6000m ± 6 m

Table IVa - S/T/D/SV DATA

Time:

Down 160918 June 1971

Up 160928 June 1971

Cast 160918 June 1971

Depth (meters)	T↓ (°C)	T↑ (°C)	T(av) (°C)	S↓ (‰)	S↑ (‰)	S(av) (‰)
0	11.7	11.3	11.50	33.84	33.97	33.91
10	10.0	10.0	10.00	33.92	33.97	33.95
20	9.5	9.5	9.50	33.93	34.94	33.98
30	9.0	9.0	9.00	34.00	34.00	34.00
40	8.9	8.8	8.85	34.00	34.04	34.02
50	8.8	8.8	8.80	34.03	34.02	34.03
60	8.7	8.8	8.75	34.03	34.03	34.03
70	8.7	8.5	8.60	34.04	34.01	34.02
80	8.5	8.5	8.50	34.00	34.01	34.00
90	8.3	8.3	8.30	34.02	34.02	34.02
100	8.3	8.3	8.30	34.04	34.03	34.04
110	8.2	8.2	8.20	34.07	34.05	34.06
120	8.1	8.2	8.15	34.08	34.06	34.07
130	8.1	8.0	8.05	34.08	34.08	34.08
140	8.0	8.0	8.00	34.10	34.10	34.10
150	8.0	8.0	8.00	34.12	34.12	34.12
160	8.0	8.1	8.05	34.13	34.13	34.13
170	7.9	8.0	7.95	34.14	34.17	34.16
180	7.9	8.0	7.95	34.15	34.18	34.16
190	7.9	8.0	7.95	34.16	34.19	34.18
200	7.9	8.0	7.95	34.19	34.19	34.19
210	7.6	7.9	7.75	34.18	34.20	34.19
220	7.5	7.8	7.65	34.17	34.20	34.18
230	7.5	7.5	7.50	34.17	34.19	34.18
240	7.3	7.5	7.40	34.14	34.17	34.16
250	7.1	7.4	7.25	34.18	34.17	34.18

TABLE IVb - S/T/D/SV DATA

Time:

Down 161508 June 1971

Up 161521 June 1971

Cast 161508 June 1971

Depth (meters)	T↓ (°C)	T↑ (°C)	T(av) (°C)	S↓ (°/oo)	S↑ (°/oo)	S(av) (°/oo)
0	11.5	11.5	11.50	33.84	34.10	33.97
10	10.0	10.0	10.00	33.84	34.00	33.92
20	9.1	9.3	9.20	33.95	33.96	33.96
30	9.0	9.0	9.00	33.97	34.04	34.01
40	8.8	8.5	8.65	33.99	34.01	34.00
50	8.6	8.5	8.55	33.96	34.01	33.98
60	8.5	8.4	8.45	34.01	34.03	34.02
70	8.5	8.3	8.40	34.01	34.03	34.02
80	8.3	8.3	8.30	34.04	34.06	34.05
90	8.2	8.3	8.25	34.06	34.07	34.06
100	8.3	8.2	8.25	34.07	34.06	34.06
110	8.3	8.2	8.25	34.08	34.07	34.08
120	8.3	8.2	8.25	34.10	34.07	34.08
130	8.3	8.2	8.25	34.11	34.08	34.10
140	8.1	8.1	8.10	34.09	34.10	34.10
150	8.0	8.1	8.05	34.07	34.12	34.10
160	8.0	8.1	8.05	34.14	34.14	34.14
170	8.1	8.0	8.05	34.17	34.16	34.16
180	8.0	8.0	8.00	34.18	34.18	34.18
190	8.0	8.0	8.00	34.18	34.18	34.18
200	7.9	8.0	7.95	34.20	34.19	34.20
210	7.9	7.9	7.90	34.21	34.19	34.20
220	7.9	7.8	7.85	34.21	34.20	34.20
230	7.8	7.8	7.80	34.21	34.21	34.21
240	7.8	7.7	7.75	34.21	34.21	34.21
250	7.6	7.6	7.60	34.22	34.21	34.21

Table IVc - S/T/D/SV DATA

Time:

Down 161959 June 1971

Up 162020 June 1971

Cast 161959 June 1971

Depth (meters)	T↓ (°C)	T↑ (°C)	T(av) (°C)	S↓ ($^{o}/oo$)	S↑ ($^{o}/oo$)	S(av) ($^{o}/oo$)
0	12.3	12.6	12.45	33.88	33.97	33.92
10	10.3	10.4	10.35	33.88	33.97	33.92
20	9.15	9.25	9.20	33.96	33.96	33.96
30	9.16	9.25	9.20	33.90	34.04	33.97
40	8.9	8.85	8.88	33.98	34.04	34.01
50	8.75	8.75	8.72	33.96	33.99	33.98
60	8.64	8.64	8.64	34.01	33.99	34.00
70	8.55	8.57	8.56	34.02	34.00	34.01
80	8.40	8.50	8.45	34.03	34.03	34.03
90	8.40	8.43	8.42	34.06	34.04	34.05
100	8.39	8.40	8.40	34.07	34.06	34.06
110	8.37	8.40	8.39	34.07	34.07	34.07
120	8.37	8.36	8.36	34.07	34.07	34.07
130	8.35	8.36	8.36	34.08	34.07	34.08
140	8.30	8.32	8.31	34.08	34.07	34.08
150	8.40	8.39	8.40	34.09	34.08	34.08
160	8.40	8.35	8.38	34.14	34.08	34.11
170	8.33	8.36	8.34	34.16	34.11	34.14
180	8.30	8.35	8.32	34.17	34.13	34.15
190	8.25	8.34	8.30	34.17	34.15	34.16
200	8.20	8.29	8.24	34.18	34.16	34.17
210	8.14	8.20	8.17	34.19	34.19	34.19
220	8.04	8.10	8.07	34.20	34.20	34.20
230	8.00	8.05	8.02	34.21	34.21	34.21
240	7.80	7.95	7.88	34.21	34.21	34.21
250	7.75	7.75	7.75	34.22	34.22	34.22

Table IVd - S/T/D/SV DATA

Time:

Down 162354 June 1971

Up - - - June 1971

Cast 162345 June 1971

Depth (meters)	T↓ (°C)	T↑ (°C)	T(av) (°C)	S↓ (^{0}/oo)	S↑ (^{0}/oo)	S(av) (^{0}/oo)
0	12.17		12.17	33.96	34.00	33.98
10	11.10		11.10	33.80	34.00	33.90
20	10.35		10.35	33.94	34.02	33.98
30				33.82	34.00	33.91
40	8.90	9.09	8.99	33.99	34.01	34.00
50	8.85	8.85	8.85	33.99	34.01	34.00
60	8.72	8.75	8.74	34.00	34.02	34.01
70	8.65	8.63	8.64	34.03	34.03	34.03
80	8.55	8.60	8.58	34.04	34.04	34.04
90	8.53	8.55	8.54	34.04	34.05	34.04
100	8.45	8.45	8.45	34.05	34.05	34.05
110	8.40	8.38	8.39	34.06	34.05	34.06
120	8.38	8.30	8.34	34.08	34.07	34.08
130	8.37	8.32	8.34	34.08	34.08	34.08
140	8.35	8.30	8.32	34.09	34.08	34.08
150	8.30	8.28	8.29	34.09	34.09	34.09
160	8.40	8.25	8.32	34.14	34.14	34.14
170	8.34	8.40	8.37	34.14	34.14	341.4
180	8.34	8.40	8.37	34.15	34.15	34.15
190	8.30	8.35	8.32	34.16	34.16	34.16
200	8.21	8.31	8.26	34.17	34.17	34.17
210	8.19	8.27	8.22	34.18	34.18	34.18
220	8.15	8.20	8.18	34.19	34.19	34.19
230	8.11	8.19	8.15	34.20	34.19	34.20
240	8.11	8.15	8.13	34.20	34.20	34.20
250	8.06	8.12	8.09	34.21	34.22	34.22

Table IVe - S/T/D/SV DATA

Time:

Down 170300 June 1971

Up - - - June 1971

Cast 170300 June 1971

Depth (Meters)	T (°C)	T (°C)	T(av) (°C)	S (^{o}/oo)	S (^{o}/oo)	S(av) (^{o}/oo)
0	9.17	9.15	9.16	33.84	33.97	33.90
10	9.17	9.15	9.16	33.94	34.08	34.01
20	9.00	9.15	9.08	33.90	33.99	33.94
30	8.90	8.91	8.90	33.96	33.99	33.98
40	8.85	8.75	8.80	33.98	34.00	33.99
50	8.65	8.70	8.68	33.96	34.00	33.98
60	8.64	8.65	8.64	34.01	34.02	34.00
70	8.62	8.61	8.61	34.02	34.02	34.02
80	8.50	8.55	8.52	34.03	34.03	34.03
90	8.49	8.49	8.49	34.05	34.05	34.05
100	8.46	8.41	8.44	34.05	34.06	34.06
110	8.50	8.47	8.48	34.09	34.09	34.09
120	8.47	8.49	8.48	34.11	34.11	34.11
130	8.40	8.45	8.42	34.12	34.12	34.12
140	8.40	8.38	8.39	34.13	34.13	34.13
150	8.30	8.38	8.34	34.14	34.14	34.14
160	8.25	8.26	8.26	34.12	34.12	34.12
170	8.14	8.16	8.15	34.11	34.12	34.12
180	8.00	8.05	8.02	34.12	34.12	34.12
190	8.15	8.01	8.08	34.11	34.13	34.12
200	8.18	8.18	8.18	34.18	34.13	34.16
210	8.10	8.11	8.10	34.19	34.20	34.20
220	8.07	8.05	8.06	34.19	34.20	34.20
230	8.00	8.03	8.02	34.21	34.21	34.21
240	7.95	7.96	7.96	34.21	34.22	34.22
250	7.85	7.81	7.83	34.21	34.22	34.22

Table Va - TRANSMISSION DATA

Time:

Cast 160603 June 1971

Depth (meter)	Time Down	T	T Corrected	Time up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	- -	- -		- -	- -		- -	- -	- -
5	0548	.459	N	0621	.260*	N	0604	.459	.779
10	0549	.490	O	0620	.300*	O	0604	.490	.713
15	0551	.693		0619	.693		0605	.693	.367
20	0551	.739	C	0617	.698	C	0604	.719	.330
30	0552	.739	O	0616	.715	O	0604	.727	.319
40	0553	.778	R	0615	.811	R	0604	.795	.229
50	0554	.852	R	0614	.834	R	0604	.843	.171
75	0555	.864	E	0612	.859	E	0604	.862	.148
100	0556	.901	C	0610	.906	C	0604	.904	.101
125	0557	.901	T	0610	.906	T	0604	.904	.101
150	0558	.906	I	0508	.906	I	0603	.906	.099
175	0559	.906	O	0607	.289*	O	0603	.906	.099
200	0600	.913	N	0605	.913	N	0603	.916	.087
225	0601	.931		0603	.926		0602	.929	.074

*DISREGARDED AS BAD DATA

Table Vb - TRANSMISSION DATA

Time:

Cast 160808 June 1971

Depth (meter)	Time Down	T	T Corrected	Time up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0754	.308		0826	.300		0810	.304	1.191
5	0754	.291*	N	0825	.332	N	0810	.332	1.103
10	0755	.703	O	0824	.734	O	0810	.718	.331
15	0756	.725		0823	.742		0810	.734	.309
20	0757	.698	C	0822	.741	C	0810	.720	.328
30	0758	.736	O	0821	.706	O	0810	.721	.327
40	0759	.838	R	0820	.828	R	0810	.833	.183
50	0800	.849	R	0819	.872	R	0810	.860	.151
75	0801	.140*	E	0818	.876	E	0810	.876	.132
100	0802	.900	C	0816	.908	C	0809	.904	.101
125	0803	.915	T	0815	.919	T	0809	.917	.087
150	0804	.916	I	0813	.919	I	0808	.918	.086
175	0805	.906	O	0812	.922	O	0808	.914	.090
200	0806	.918	N	0811	.908	N	0808	.913	.091
225	0806	.918		0810	.924		0808	.921	.082
250	0807	.926		0807	.926		0807	.926	.077

*DISREGARDED AS BAD DATA

Table Vc - TRANSMISSION DATA

Time:

Cast 161025 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	1017	.486		1054	.727		1017	.486	.722
5	1020	.570	N	1053	.727	N	1020	.570	.502
10	1022	.650	O	1052	.697	O	1022	.650	.431
15	1023	.680		1051	.529		1023	.680	.386
20	1024	.605	C	1050	.576	C	1024	.605	.502
30	1025	.690	O	1049	.646	O	1025	.690	.371
40	1026	.764	R	1048	.752	R	1026	.764	.269
50	1026	.795	R	1047	.806	R	1026	.795	.229
75	1027	.817	E	1045	.861	E	1027	.817	.202
100	1028	.872	C	1044	.862	C	1028	.872	.137
125	1029	.863	T	1043	.840	T	1029	.863	.147
150	1030	.854	I	1041	.866	I	1030	.854	.158
175	1031	.844	O	1040	.835	O	1031	.844	.170
200	1032	.873	N	1039	.840	N	1032	.873	.136
225	1033	.869		1038	.879		1033	.869	.140
250	1034	.320*		1036	.320*		1034	.320*	.140

*DISREGARDED AS BAD DATA NOTE: UPCAST INVALID (BATTERY LOW)

TABLE Vd - TRANSMISSION DATA

Time:

Cast 161355 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	1323	.724	.724*	1358	.618	.578	SEE	NEXT	TABLE
5	1324	.720	.719*	1357	.619	.580			
10	1324	.720	.719*	1357	.612	.573			
15	1325	.632	.629*	1356	.534	.497			
20	1325	.632	.629*	1354	.572	.536			
30	1326	.772	.767	1353	.754	.719			
40	1326	.795	.790	1352	.788	.754			
50	1327	.822	.816	1351	.885	.853			
75	1328	.892	.885	1349	.846	.816			
100	1329	.898	.891	1347	.804	.777			
125	1330	.808	.799	1346	.815	.789			
150	1331	.825	.815	1344	.860	.836			
175	1332	.868	.857	1343	.844	.821			
200	1338	.890	.873	1342	.870	.848			
225	1339	.920	.901	1340	.920	.900			
250	1339	.920	.901	1339	.920	.901			

*DISREGARDED AS BAD DATA

TABLE Vd (cont'd) - TRANSMISSION DATA

Time:

Cast 161355 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	1358	.518	.578	1428	.558	.483*	1355	.578	.548
5	1359	.606	.565	1427	.565	.592*	1355	.572	.559
10	1359	.606	.565	1426	.638	.566	1355	.569	.564
15	1400	.485	.443	1425	.401	.311*	1355	.470	.755
20	1401	.519	.475	1425	.512	.442	1355	.505	.683
30	1402	.735	.690	1424	.729	.659*	1355	.704	.351
40	1403	.875	.830	1423	.841	.773	1355	.792	.233
50	1403	.890	.845	1422	.791	.724*	1355	.849	.164
75	1405	.768	.720	1421	.791	.725	1355	.768	.264
100	1406	.811	.761	1419	.810	.746	1355	.769	.263
125	1406	.856	.806	1418	.836	.776	1355	.798	.226
150	1407	.860	.810	1417	.794	.733	1355	.823	.194
175	1408	.881	.830	1415	.838	.778	1355	.825	.192
200	1409	.920	.867	1413	.912	.855	1355	.858	.153
225	1410	.909	.854	1412	.916	.860	1355	.877	.131
250	1411	.909	.854	1411	.909	.854	1355	.878	.130

*DISREGARDED AS BAD DATA

TABLE Ve - TRANSMISSION DATA

Time:

Cast 16 1627 July 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	1606	.422	.422	1644	.315	.336*	1625	.422	.863
5	1607	.564	.565	1644	.232	.253*	1626	.565	.571
10	1608	.378	.379	1643	.250	.271	1625	.379	.970
15	1610	.494	.499	1642	.522	.700	1620	.700	.357
20	1611	.544	.549	1641	.522	.541	1628	.545	.607
30	1612	.717	.721	1640	.740	.756	1628	.738	.304
40	1616	.339	.345*	1640	.819	.838	1628	.838	.177
50	1617	.847	.853	1639	.837	.855	1620	.854	.158
75	1620	.834	.842	1638	.688	.706	1628	.842	.172
100	1621	.598	.606*	1636	.802	.818	1628	.818	.201
125	1623	.813	.822	1635	.756	.772	1629	.797	.227
150	1624	.813	.823	1634	.806	.821	1629	.822	.196
175	1625	.843	.853	1633	.830	.845	1629	8.49	.164
200	1626	.865	.876	1632	.860	.874	1629	.875	.134
225	1627	.257	.269*	1631	.856	.870	1629	.870	.139
250	1628	.854	.866	1628	.854	.866	1628	.866	.144

*DISREGARDED AS BAD DATA

TABLE Vf - TRANSMISSION DATA

Time:

Cast 161811 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	1754	.521	.521	1827	.395	.470	1810	.495	.703
5	1755	.521	.524	1826	.395	.469	1810	.495	.703
10	1756	.152	.158*	1825	.292	.364	1810	.364	1.011
15	1759	.309	.321	1824	.321	.390	1811	.349	1.053
20	1800	.598	.613	1823	.558	.624	1812	.611	.493
30	1801	.475	.491 *	1822	.715	.780	1812	.780	.248
40	1802	.757	.777	1821	.734	.797	1812	.787	.240
50	1802	.734	.754	1820	.750	.818	1811	.786	.241
75	1803	.773	.794	1819	.782	.840	1811	.817	.202
100	1804	.775	.799	1817	.770	.824	1811	.812	.208
125	1805	.775	.800	1816	.759	.809	1811	.804	.218
150	1806	.889	.916	1815	.800	.848*	1811	.916	.087
175	1807	.858	.888*	1813	.856	.900	1810	.900	.105
200	1808	.858	.890	1812	.855	.897	1810	.903	.113
225	1809	.856	.891	1811	.855	.895	1810	.893	.113
250	1810	.856	.893	1810	.856	.893	1810	.893	.113

*DISREGARDED AS BAD DATA

TABLE Vg - TRANSMISSION DATA

Time:

Cast 162113 June 1971

Depth (meter)	Time Down	T	T Corrected	Time up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	2052	.435	.434	2133	.372	.350*	2112	.434	.835
5	2054	.443	.442	2132	.379	.353*	2112	.442	.816
10	2055	.433	.431	2132	.378	.352*	2113	.431	.842
15	2057	.377	.374	2131	.322	.296*	2114	.374	.984
20	2058	.356	.352	2130	.344	.319	2114	.335	1.094
30	2059	.706	.701	2128	.725	.701	2113	.701	.355
40	2100	.736	.731	2127	.735	.712	2113	.721	.327
50	2102	.757	.750	2126	.764	.742	2114	.746	.293
75	2103	.786	.779	2125	.782	.760	2114	.769	.263
100	2104	.808	.800	2123	.258	*	2114	.800	.223
125	2105	.816	.807	2119	.814	.796	2112	.801	.222
150	2106	.812	.803	2117	.810	.793	2112	.798	.226
175	2108	.876	.865	2116	.875	.869	2112	.867	.143
200	2109	.895	.884	2115	.893	.878	2112	.881	.127
225	2111	.881	.868	2113	.870	.865	2112	.866	.144
250	2112	.882	.869	2112	.882	.869	2112	.869	.140

*DISREGARDED AS BAD DATA

TABLE Vh - TRANSMISSION DATA

Time:

Cast 162317 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	2301	.275		2333	.217*		2317	.275	1.291
5	2302	.276	N	2332	.217*	N	2317	.276	1.287
10	2303	.276	O	2332	.218*	O	2317	.276	1.287
15	2304	.317		2330	.284		2317	.300	1.203
20	2305	.458	C	2330	.492	C	2317	.470	.755
30	2306	.643	O	2329	.672	O	2317	.657	.420
40	2307	.726	R	2328	.724	R	2317	.725	.322
50	2308	.803	R	2327	.789	R	2317	.796	.228
75	2309	.852	E	2326	.854	E	2317	.853	.159
100	2311	.799	C	2324	.792	C	2317	.795	.229
125	2312	.805	T	2323	.802	T	2317	.801	.222
150	2313	.820	I	2321	.822	I	2317	.821	.147
175	2314	.844	O	2320	.832	O	2317	.838	.177
200	2315	.880	N	2319	.888	N	2317	.884	.123
225	2316	.877		2318	.877		2317	.877	.131
250	2317	.877		2317	.877		2317	.877	.131

*DISREGARDED AS BAD DATA

TABLE Vi - TRANSMISSION DATA

Time:

Cast 170225 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0212	.210	.210	0243	.228	.211	0227	.211	1.556
5	0213	.210	.210	0242	.238	.222	0228	.216	1.532
10	0213	.215	.215	0242	.239	.222	0227	.218	1.523
15	0215	.339	.337*	0241	.629	.613	0228	.613	.489
20	0215	.747	.745	0238	.747	.733	0227	.739	.302
30	0216	.699	.697	0237	.708	.694	0226	.695	.364
40	0217	.264	.761	0236	.763	.750	0226	.755	.281
50	0218	.764	.761	0235	.766	.753	0226	.757	.278
75	0219	.859	.855	0234	.868	.856	0226	.856	.155
100	0220	.828	.824	0233	.830	.818	0226	.821	.197
125	0221	.801	.796	0231	.818	.807	0226	.801	.222
150	0222	.873	.868	0230	.870	.860	0226	.864	.146
175	0222	.858	.853	0229	.864	.855	0225	.854	.158
200	0223	.868	.862	0228	.856	.847	0225	.854	.158
225	0224	.881	.874	0226	.878	.870	0225	.872	.137
250	0225	.801	.874	0225	.881	.874	0225	.874	.135

*DISREGARDED AS BAD DATA

TABLE Vj - TRANSMISSION DATA

Time:

Cast 170421 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0411	.184	.182	0434	.186	.176	0424	.179	1.720
5	0411	.184	.182	0438	.187	.178	0424	.180	1.715
10	0412	.184	.182*	0437	.246	.247	0424	.247	1.398
15	0413	.697	.694	0437	.722	.713	0425	.703	.352
20	0413	.713	.710	0436	.704	.695	0424	.702	.354
30	0414	.712	.709	0435	.762	.753	0424	.731	.313
40	0415	.784	.781	0434	.851	.843	0424	.832	.184
50	0415	.848	.845	0434	.851	.843	0424	.844	.170
75	0416	.838	.835	0433	.851	.843	0424	.839	.176
100	0418	.226	.222*	0431	.795	.788	0424	.788	.238
125	0419	.804	.800	0430	.778	.771	0424	.785	.242
150	0421	.847	.842	0429	.852	.845	0425	.843	.171
175	0422	.854	.849	0428	.854	.847	0425	.848	.065
200	0422	.864	.859	0426	.868	.862	0424	.860	.151
225	0423	.877	.872	0425	.873	.867	0424	.869	.140
250	0424	.872	.866	0424	.872	.866	0424	.866	.144

*DISREGARDED AS BAD DATA

TABLE Vk - TRANSMISSION DATA

Time:

Cast 170543 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0534	.253	.252	0606	.189	.181*	0550	.252	1.378
5	0534	.253	.252	0606	.185	.177*	0550	.252	1.378
10	0536	.503	.502	0605	.472	.464	0550	.484	.726
15	0537	.663	.662	0604	.684	.677	0550	.664	.409
20	0537	.663	.662	0603	.692	.685	0550	.673	.396
30	0538	.761	.759	0557	.777	.771	0547	.765	.268
40	0539	.849	.847	0556	.859	.853	0547	.850	.162
50	0540	.855	.853	0556	.228	.222*	0548	.853	.159
75	0540	.808	.806	0554	.798	.795	0547	.800	.223
100	0541	.869	.867	0552	.874	.869	0546	.868	.142
125	0542	.876	.874	0551	.869	.865	0546	.869	.140
150	0543	.867	.864	0550	.869	.865	0546	.865	.145
175	0544	.870	.867	0549	.869	.865	0546	.866	.144
200	0545	.868	.865	0548	.869	.865	0546	.865	.145
225	0545	.869	.866	0547	.869	.866	0546	.866	.144
250	0546	.869	.866	0546	.869	.866	0546	.866	.144

*DISREGARDED AS BAD DATA

TABLE VI - TRANSMISSION DATA

Time:

Cast 170731 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0709	.173	.173	0758	.126	.119*	0733	.173	1.754
5	0710	.168	.168	0757	.123	.117	0732	.168	1.784
10	0715	.653	.652	0753	.193	.187	0735	.652	.428
15	0716	.647	.646	0750	.639	.636	0733	.641	.445
20	0717	.680	.679	0749	.639	.633	0733	.656	.422
30	0718	.686	.685	0748	.694	.689	0733	.687	.375
40	0719	.752	.751	0747	.824	.822	0733	.786	.377
50	0720	.801	.800	0746	.869	.859	0733	.829	.188
75	0721	.871	.869	0745	.881	.846	0733	.855	.157
100	0721	.887	.885	0744	.894	.889	0732	.887	.126
125	0722	.876	.874	0743	.878	.869	0732	.871	.138
150	0723	.876	.874	0741	.879	.875	0732	.874	.135
175	0724	.881	.870	0740	.885	.881	0732	.880	.128
200	0725	.890	.888	0733	.896	.875	0728	.881	.127
225	0726	.894	.892	0728	.731	.886	0728	.889	.118
250	0727	.872	.869	0727	.872	.869	0727	.869	.140

*DISREGARDED AS BAD DATA

TABLE Vm - TRANSMISSION DATA

Time:

Cast 170959 June 1971

Depth (meter)	Time Down	T	T Corrected	Time Up	T	T Corrected	Time Averaged	T Averaged	α (m^{-1})
2	0944	.060	.066*	1015	.121	.165	0959	.165	1.802
5	0944	.060	.066*	1015	.121	.165	0959	.165	1.802
10	0946	.058	.066	1014	.123	.166*	1000	.166	1.796
15	0947	.579	.588	1012	.571	.611	0959	.599	.512
20	0948	.584	.594	1011	.581.	.620	0959	.607	.499
30	0948	.677	.687	1009	.688	.725	0950	.706	.348
40	0949	.736	.748	1008	.791	.827	0958	.781	.243
50	0950	.833	.846	1007	.849	.883	0958	.864	.146
75	0951	.833	.847	1005	.834	.866	0958	.856	.158
100	0952	.882	.898	1004	.880	.910	0958	.904	.101
125	0953	.856	.873	1003	.868	.898	0958	.885	.122
150	0954	.856	.864	1003	.868	.898	0958	.881	.127
175	0956	.865	.885	1002	.868	.896	0959	.890	.116
200	0956	.875	.895	1001	.878	.905	0958	.900	.105
225	0957	.864	.886	0959	.865	.889	0958	.887	.120
250	0958	.870	.893	0958	.870	.893	0958	.893	.113

*DISREGARDED AS BAD DATA

TABLE VIa - CONVERSION TABLE: Feet to Meters

FEET	METERS
25.00	7.62
50.00	15.24
75.00	22.86
100.00	30.48
125.00	38.10
150.00	45.72
175.00	53.34
200.00	60.96
225.00	68.58
250.00	76.20
275.00	83.82
300.00	91.44
325.00	99.06
350.00	106.68
375.00	114.30
400.00	121.92
425.00	129.54
450.00	137.16
475.00	144.78
500.00	152.40
525.00	160.02
550.00	167.64
575.00	175.26
600.00	182.88
625.00	190.50
650.00	198.12
675.00	205.74
700.00	213.36
725.00	220.98
750.00	228.60
775.00	236.22
800.00	243.84

TABLE VIb - CONVERSION TABLE: Degrees Fahrenheit to Degrees Celsius

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
40.00	4.44	43.00	6.11	46.00	7.78	49.00	9.44	52.00	11.11
40.10	4.50	43.10	6.17	46.10	7.83	49.10	9.50	52.10	11.17
40.20	4.56	43.20	6.22	46.20	7.89	49.20	9.56	52.20	11.22
40.30	4.61	43.30	6.28	46.30	7.94	49.30	9.61	52.30	11.28
40.40	4.67	43.40	6.33	46.40	8.00	49.40	9.67	52.40	11.33
40.50	4.72	43.50	6.39	46.50	8.06	49.50	9.72	52.50	11.39
40.60	4.78	43.60	6.44	46.60	8.11	49.60	9.78	52.60	11.44
40.70	4.83	43.70	6.50	46.70	8.17	49.70	9.83	52.70	11.50
40.80	4.89	43.80	6.56	46.80	8.22	49.80	9.89	52.80	11.56
40.90	4.94	43.90	6.61	46.90	8.28	49.90	9.94	52.90	11.61
41.00	5.00	44.00	6.67	47.00	8.33	50.00	10.00	53.00	11.67
41.10	5.06	44.10	6.72	47.10	8.39	50.10	10.06	53.10	11.72
41.20	5.11	44.20	6.78	47.20	8.44	50.20	10.11	53.20	11.78
41.30	5.17	44.30	6.83	47.30	8.50	50.30	10.17	53.30	11.83
41.40	5.22	44.40	6.89	47.40	8.56	50.40	10.22	53.40	11.89
41.50	5.28	44.50	6.94	47.50	8.61	50.50	10.28	53.50	11.94
41.60	5.33	44.60	7.00	47.60	8.67	50.60	10.33	53.60	12.00
41.70	5.39	44.70	7.06	47.70	8.72	50.70	10.39	53.70	12.06
41.80	5.44	44.80	7.11	47.80	8.78	50.80	10.44	53.80	12.11
41.90	5.50	44.90	7.17	47.90	8.83	50.90	10.50	53.90	12.17
42.00	5.56	45.00	7.22	48.00	8.89	51.00	10.56	54.00	12.22
42.10	5.61	45.10	7.28	48.10	8.94	51.10	10.61	54.10	12.28
42.20	5.67	45.20	7.33	48.20	9.00	51.20	10.67	54.20	12.33
42.30	5.72	45.30	7.39	48.30	9.06	51.30	10.72	54.30	12.39
42.40	5.78	45.40	7.44	48.40	9.11	51.40	10.78	54.40	12.44
42.50	5.83	45.50	7.50	48.50	9.17	51.50	10.83	54.50	12.50
42.60	5.89	45.60	7.56	48.60	9.22	51.60	10.89	54.60	12.56
42.70	5.94	45.70	7.61	48.70	9.28	51.70	10.94	54.70	12.61
42.80	6.00	45.80	7.67	48.80	9.33	51.80	11.00	54.80	12.67
42.90	6.06	45.90	7.72	48.90	9.39	51.90	11.06	54.90	12.72
								55.00	12.78

TABLE VI c - XBT DATA*

Date: 16 June 1971

TIME	0600	0630	0742	0800	0900	1000	1030	1130	1230
DEPTH (Feet)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)
0	52.8	53.3	53.3	53.3	53.7	53.8	53.0	53.2	53.0
25	52.9	53.8	53.1	53.2	54.0	53.0	53.0	53.0	53.0
50	50.0	52.0	52.0	50.8	51.2	50.8	51.0	50.9	51.0
75	49.2	50.0	50.0	49.9	50.6	50.3	50.7	50.8	50.8
100	48.9	50.0	49.3	49.1	50.0	49.9	50.0	49.9	50.1
25	48.8	50.0	48.8	49.0	49.5	49.0	49.3	49.2	49.2
50	48.2	50.4	48.8	48.8	49.2	49.0	49.1	49.1	49.0
75	48.2	50.1	48.8	48.7	49.0	48.7	49.0	49.0	48.5
200	48.2	50.0	48.6	48.7	49.0	48.7	48.8	48.9	48.4
25	47.9	50.0	48.4	48.6	48.9	48.6	48.7	48.8	48.0
50	47.9	50.0	48.4	48.6	48.9	48.5	48.7	48.7	48.0
75	47.3	49.6	48.1	48.2	48.7	48.0	48.0	48.2	47.0
300	47.2	49.3	48.0	48.0	48.4	47.9	47.9	48.1	47.7
25	47.3	49.2	47.8	47.8	48.2	47.7	47.9	48.0	47.7
50	47.3	49.1	47.7	47.7	48.1	47.7	47.9	47.9	47.4
75	47.5	49.1	47.6	47.6	48.0	47.6	47.8	47.8	47.3
400	47.0	49.0	47.4	47.5	47.9	47.5	47.8	47.8	47.3
25	47.0	49.1	47.3	47.3	47.7	47.4	47.8	47.7	47.3
50	46.9	48.9	47.2	47.2	47.7	47.3	47.8	47.7	47.3
75	46.9	48.8	47.2	47.2	47.6	47.3	47.8	47.6	47.1
500	46.8	48.8	47.1	47.2	47.4	47.2	47.8	47.5	47.0
25	46.0	48.8	47.1	47.1	47.4	47.1	47.8	47.3	47.0
50	47.0	48.7	47.0	47.1	47.4	47.1	47.8	47.2	47.0
75	47.0	48.7	47.0	47.0	47.3	47.3	47.8	47.6	46.9
600	46.8	48.8	47.0	47.0	47.1	47.3	47.2	47.3	46.9
25	46.7	48.7	47.0	47.0	47.1	47.2	47.2	47.2	47.0
50	46.6	48.7	46.8	46.9	47.0	47.1	47.3	47.3	46.9
75	46.0	4.87	46.7	46.9	46.9	47.0	47.3	47.2	46.9
700	46.0	48.0	46.6	46.7	46.8	47.0	47.2	47.1	46.8
25	46.0	47.9	46.3	46.6	46.7	46.9	47.2	47.0	46.8
50	46.0	47.8	46.2	46.5	46.5	46.7	47.2	47.0	46.8
75	45.7	47.9	46.2	46.2	46.4	46.6	47.1	47.0	46.8
800	45.6	47.7	46.0	46.3	46.0	46.2	47.0	46.5	46.7

* See Tables VIa and VIb for Conversion of Feet to Meters and Degrees Fahrenheit to Degrees Celsius.

TABLE VI c - XBT DATA*

Date: 16 June 1971

TIME	1430	1600	1700	1800	2000	2200	2340
DEPTH (Feet)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)
0	53.3	53.5	54.2	53.9	54.0	54.0	54.0
25	53.3	53.3	54.0	53.9	53.9	54.0	54.0
50	53.0	52.0	51.5	53.4	51.0	53.1	51.0
75	51.0	49.0	49.5	51.0	49.9	50.2	50.8
100	50.3	48.9	49.2	49.2	49.8	50.0	50.5
25	49.0	48.8	48.1	48.9	48.5	48.4	48.3
50	48.8	48.2	47.9	48.0	48.1	48.1	48.1
75	48.5	48.1	47.7	47.8	47.9	48.0	48.1
200	48.4	47.8	47.5	47.7	47.8	47.8	48.0
25	48.3	47.5	47.3	47.6	47.8	47.8	47.8
50	48.3	47.2	47.3	47.5	47.5	47.8	47.7
75	48.2	47.2	47.2	47.4	47.3	47.8	47.6
300	48.2	47.0	47.1	47.3	47.2	47.8	47.5
25	48.2	47.1	47.1	47.2	47.2	47.8	47.4
50	48.0	47.1	47.1	47.2	47.2	47.7	47.3
75	48.0	47.2	47.1	47.2	47.2	47.8	[illegible]
400	48.0	47.3	47.1	47.2	47.2	47.8	47.2
25	47.9	47.1	47.1	47.2	47.2	47.9	47.2
50	47.9	47.0	47.1	47.3	47.2	47.9	47.2
75	47.9	47.0	47.2	47.1	47.1	47.8	47.2
500	47.8	46.9	47.1	47.1	47.3	47.8	47.1
25	47.8	46.7	47.1	47.1	47.2	47.7	47.2
50	47.8	46.7	47.1	47.0	47.2	47.7	47.2
75	47.8	46.8	47.1	47.0	47.2	47.8	47.1
600	47.8	46.8	47.1	46.9	47.2	47.8	47.1
25	47.7	46.7	47.0	46.9	47.1	47.7	47.0
50	47.6	46.7	46.8	46.8	47.0	47.5	46.9
75	47.5	46.6	46.8	46.7	47.0	47.4	46.9
700	47.5	46.6	46.7	46.5	46.9	47.3	46.9
25	47.4	46.5	46.5	46.4	46.8	47.2	46.8
50	47.3	46.5	46.5	46.3	46.7	47.1	46.8
75	47.2	46.3	46.4	46.3	46.6	46.9	46.7
800	46.7	46.2	46.3	46.2	46.5	46.8	46.7

*See Tables VIa and VIb for Conversionof Feet to Meters and Degrees Fahrenheit to Degrees Celsius.

TABLE VI d - XBT DATA*

Date: 17 June 1971

TIME	0030	0200	0300	0400	0512	0600	0700	0810	0934
DEPTH (Feet)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)	T (°F)
0	54.1	54.0	53.9	54.0	53.3	53.2	53.0	53.1	53.3
25	54.0	54.0	53.1	53.9	52.1	53.1	52.2	52.2	53.0
50	52.9	52.0	51.2	51.1	51.2	51.2	50.5	51.2	51.8
75	50.9	51.0	51.0	50.2	49.1	49.0	49.1	50.0	51.0
100	50.6	49.0	49.0	48.6	48.5	48.1	48.4	49.0	49.5
25	49.0	48.6	48.5	48.1	48.2	48.0	48.0	48.5	49.0
50	48.1	48.2	48.2	48.0	48.1	48.0	48.0	48.3	48.2
75	48.0	48.0	48.0	47.8	48.0	47.8	47.8	48.0	48.0
200	47.8	47.9	48.0	47.8	47.9	47.8	47.8	47.9	48.0
25	47.6	47.7	47.9	47.5	47.9	47.7	47.7	47.8	47.9
50	47.6	47.7	47.9	47.5	47.9	47.6	47.7	47.7	47.8
75	47.5	47.7	47.8	47.4	47.7	47.5	47.5	47.4	47.5
300	47.4	47.6	47.7	47.3	47.5	47.4	47.4	47.3	47.3
25	47.3	47.5	47.5	47.2	47.5	47.4	47.5	47.4	47.4
50	47.1	47.2	47.5	47.2	47.5	47.4	47.3	47.1	47.4
75	47.0	47.2	47.3	47.1	47.5	47.3	47.2	47.2	47.3
400	47.0	47.1	47.3	47.0	47.5	47.3	47.2	47.2	47.2
25	46.9	47.1	47.3	47.2	47.3	47.2	47.1	47.2	47.2
50	46.9	47.3	47.3	47.2	47.2	47.2	47.0	47.1	47.1
75	47.0	47.0	47.3	47.0	47.2	47.1	47.0	47.1	47.1
500	46.9	47.0	47.2	47.0	47.1	47.1	47.0	47.1	47.0
25	47.0	47.0	47.2	46.9	47.1	47.0	47.0	47.1	47.0
50	47.1	47.0	47.0	46.7	47.1	47.0	47.0	47.1	47.0
75	47.1	46.9	47.0	46.6	47.0	46.6	46.9	47.0	47.0
600	47.0	46.9	46.9	46.6	47.0	46.6	46.9	47.0	47.0
25	47.0	46.8	46.5	47.0	46.8	46.8	46.9	46.9	46.9
50	46.9	46.8	46.7	46.7	46.9	46.8	46.7	46.9	46.7
75	46.9	46.9	47.0	46.8	46.9	46.8	46.4	46.8	46.7
700	46.8	46.9	47.0	46.7	46.9	46.7	46.4	46.7	46.5
25	46.8	46.9	46.9	46.6	46.9	46.6	46.3	46.4	46.5
50	46.7	46.9	46.9	46.6	46.8	46.6	46.3	46.3	46.5
75	46.7	46.8	46.8	46.5	46.6	46.4	46.2	46.3	46.3
800	46.6	46.8	46.8	46.3	46.4	46.3	46.1	46.2	46.3

*See Tables VIa and VIb for Conversion of Feet to Meters and Degrees Fahrenheint to Degrees Celsius.

TABLE VIIa - PARTICULAR MATTER DATA

Date: 16 June 1971 Time: 1235

Sample Depth (m)	Cumulative Volume ($m^3 \times 10^{-15}$/2ml)	Cumulative Area ($m^2 \times 10^{-10}$/2ml)	Cumulative Count	Channel Number and Equivalent Spherical Diameter (μ)			
				13 (1.59)	12 (2.00)	11 (2.52)	10 (3.17)
0	2762	560	136,932	87,708	33,650	5,102	2,130
5	1614	424	142,549	82,425	39,694	8,808	2,899
10	5770	856	155,441	89,704	37,745	11,161	4,701
15	4475	680	129,349	84,401	29,065	5,226	2,474
30	2462	472	90,727	60,711	15,431	4,798	2,810
50	876	256	75,434	43,062	12,865	2,962	1,696
75	598	201	51,429	32,740	10,072	2,390	1,604
100	1173	278	96,135	56,813	19,631	7,275	4,297
125							
150	765	236	53,624	32,366	11,588	2,730	1,727
175							
200	923	268	80,396	53,182	15,175	3,911	2,331
225							
250							

TABLE VII a (Cont'd) - PARTICULAR MATTER DATA

Date: 16 June 1971 Time 1235

Sample Depth (m)	Channel Number and Equivalent Spherical Diameter (μ)									
	9 (4.00)	8 (5.04)	7 (6.35)	6 (8.00)	5 (10.08)	4 (12.7)	3 (16.0)	2 (20.2)	1 (25.4)	0 (32.0)
0	5,300	1,281	576	439	277	151	125	101	60	32
5	5,500	1,564	764	384	273	128	64	22	18	10
10	6,369	2,280	1,268	764	413	309	292	233	133	69
15	5,125	1,200	585	475	230	109	100	122	165	72
30	4,851	950	457	286	138	77	54	52	70	42
50	3,978	477	217	129	70	28	24	12	7	4
75	3,737	401	247	117	67	25	11	10	5	3
100	5,381	1,311	753	395	166	64	30	13	2	4
125										
150	4,017	536	316	174	88	42	20	9	3	8
175										
200	4,229	731	419	229	103	47	16	7	9	7
225										
250										

TABLE VIIb - PARTICULATE MATTER DATA

Date: 16 June 1971 Time: 1725

Sample Depth (m)	Cumulative Volume ($m^3 \times 10^{-15}$/2ml)	Cumulative Area ($m^2 \times 10^{-10}$/2ml)	Cumulative Count	Channel Number and Equivalent Spherical Diameter (μ)			
				13 (1.59)	12 (2.00)	11 (2.52)	10 (3.17)
0	33,176	2398	184,275	110,905	37,763	11,080	4,594
5	14,284	1479	233,274	129,740	54,519	21,680	8,819
10	12,206	1199	140,135	90,326	29,625	7,321	3,071
15	3,749	620	188,475	126,992	44,328	7,114	2,548
30	2,132	429	74,333	49,003	13,841	3,359	2,219
50	1,055	293	87,228	54,328	17,163	5,635	3,330
75	1,023	291	72,859	43,211	14,925	4,991	3,071
100	995	282	77,727	48,141	15,505	4,766	2,804
125							
150	628	206	53,800	33,565	10,869	2,537	1,714
175							
200							
225							
250							

TABLE VII b (Cont'd) - PARTICULATE MATTER DATA

DATE: 16 June 1971 Time: 1725

Sample Depth (m)	Channel Number and Equivalent Spherical Diameter (μ)									
	9 (4.00)	8 (5.04)	7 (6.35)	6 (8.00)	5 (10.08)	4 (12.7)	3 (16.0)	2 (20.2)	1 (25.4)	0 (32.0)
0	5,336	2,133	1,575	1,628	1,604	1,534	2,723	2,244	725	431
5	7,780	3,392	2,714	1,684	720	545	531	454	450	246
10	5,052	1,366	833	681	379	186	235	343	404	313
15	4,878	1,046	533	382	235	93	87	81	80	78
30	4,347	641	346	193	100	74	56	64	53	37
50	4,789	962	502	298	125	53	22	8	4	9
75	4,780	921	496	225	139	55	17	10	11	7
100	4,675	884	453	282	114	56	25	8	7	7
125										
150	3,986	538	279	159	95	30	16	6	4	2
175										
200										
225										
250										

TABLE VIIc - PARTICULATE MATTER DATA

Date: 16 June 1971 Time: 2220

Sample Depth (m)	Cumulative Volume ($m^3 \times 10^{-15}$/2ml)	Cumulative Area ($m^2 \times 10^{-10}$/2ml)	Cumulative Count	Channel Number and Equivalent Spherical Diameter (μ)			
				13 (1.59)	12 (2.00)	11 (2.52)	10 (3.17)
0	9172	1055	203,096	137,227	45,200	10,288	3,407
5	9624	1018	120,707	93,619	15,385	4,313	1,862
10	11,118	1130	141,764	100,498	25,273	7,067	2,580
15							
30	1096	320	78,199	50,618	12,539	5,479	4,613
50	581	198	53,940	37,823	7,703	3,513	2,235
75	788	242	56,070	34,499	9,736	5,082	3,002
100	808	250	63,652	39,297	11,604	5,717	3,307
125							
150	520	183	42,226	28,422	5,850	3,363	2,082
175							
200	282	119	29,443	20,772	4,654	1,752	962
225							
250	351	138	42,246	30,632	6,206	2,441	1,383

TABLE VIIc (Cont'd) - PARTICULATE MATTER DATA

Date: 16 June 1971 Time: 2220

Sample Depth (m)	Channel Number and Equivalent Spherical Diameter (μ)									
	9 (4.00)	8 (5.04)	7 (6.35)	6 (8.00)	5 (10.08)	4 (12.7)	3 (16.0)	2 (20.2)	1 (25.4)	0 (32.0)
0	2,308	1,669	875	481	270	230	341	336	282	182
5	1,614	1,311	635	436	236	126	223	334	340	223
10	1,820	1,403	813	493	294	183	267	425	417	231
15										
30	2,582	1,171	604	384	113	45	16	17	7	11
50	1,280	658	373	205	35	42	12	4	5	2
75	1,796	961	516	262	129	52	20	5	5	5
100	1,848	935	465	261	129	49	19	14	3	4
125										
150	1,133	660	388	181	73	40	23	3	1	2
175										
200	622	333	196	79	43	11	10	1	2	1
225										
250	810	403	204	107	33	13	4	1	1	3

TABLE VIId - PARTICULATE MATTER DATA

Date: 17 June 1971 Time: 0845

Sample Depth (m)	Cumulative Volume ($m^3 \times 10^{-15}$/2ml)	Cumulative Area ($m^2 \times 10^{-10}$/2ml)	Cumulative Count	Channel Number and Equivalent Spherical Diameter (μ)			
				13 (1.59)	12 (2.00)	11 (2.52)	10 (3.17)
0	15,134	1493	188,050	123,860	34,837	10,942	5,115
5	16,693	1452	168,167	113,777	33,629	9,033	3,530
10	12,858	1226	123,895	86,879	20,613	6,370	2,889
15	3,180	563	108,039	79,127	16,098	4,669	2,747
30	1,333	342	85,152	55,880	14,996	5,646	3,635
50	688	225	45,833	30,739	7,121	3,016	2,255
75	530	188	55,133	40,087	8,692	2,697	1,723
100	856	248	53,218	39,406	6,887	2,933	1,843
125							
150	2,217	425	70,167	51,996	10,844	3,001	1,709
175							
200	554	186	45,259	34,343	5,509	2,369	1,391
225							
250	389	154	55,517	42,857	7,047	2,398	1,512

TABLE VIId (Cont'd) - PARTICULATE MATTER DATA

Date: 17 June 1971 Time: 0845

Sample Depth (m)	Channel Number and Equivalent Spherical Diameter (μ)									
	9 (4.00)	8 (5.04)	7 (6.35)	6 (8.00)	5 (10.08)	4 (12.7)	3 (16.0)	2 (20.2)	1 (25.4)	0 (32.0)
0	3,759	2,989	1,906	1,010	716	837	745	636	455	243
5	2,230	1,580	1,017	739	418	266	324	597	669	358
10	2,013	1,537	965	628	301	214	250	453	501	282
15	2,125	1,462	752	378	203	139	87	83	89	53
30	2,526	1,205	692	381	150	41	29	20	14	17
50	1,353	621	354	187	99	41	18	17	8	4
75	907	484	261	153	70	27	19	6	4	3
100	1,039	517	262	150	75	34	19	21	23	8
125										
150	1,099	573	323	213	101	48	64	94	66	36
175										
200	788	413	219	120	54	17	14	6	9	7
225										
250	866	440	213	102	55	16	6	4	2	1

TABLE VIIIa - DENSITY DATA

Date: 16 June 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
0603	5	25.853	- -
	10	25.905	1.04
	15	25.957	.88
	20	26.176	1.09
	30	26.291	.62
	40	26.339	.50
	50	26.795	.27
	75	26.403	.14
	100	26.465	.23
	125	26.519	.22
	150	26.574	.08
	175	26.558	.14
	200	26.643	.22
	225	26.671	- -
0808	5	25.816	- -
	10	25.905	1.59
	15	26.064	.97
	20	26.159	.95
	30	26.275	.55
	40	26.307	.27
	50	26.331	.10
	75	26.323	.20
	100	26.434	.28
	125	26.473	.21
	150	26.543	.16
	175	26.558	.14
	200	26.613	.14
	225	26.625	- -

TABLE VIIIa(Cont'd) - DENSITY DATA

Date: 16 June 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
1025	5	25.853	
	10	25.924	
	15	26.064	
	20	26.107	
	30	26.191	
	40	26.274	
	50	26.298	
	75	26.339	
	100	26.419	
	125	26.458	
	150	26.497	
	175	26.497	
	200	26.583	
	225	26.551	
1355	5	25.823	---
	10	25.826	.34
	15	25.861	.82
	20	25.986	1.66
	30	26.165	1.22
	40	26.291	1.01
	50	26.308	.24
	75	26.387	.17
	100	26.395	.09
	125	26.434	.14
	150	26.465	.14
	175	26.505	.22
	200	26.575	.16
	225	26.590	---

TABLE VIIIa (Cont'd) - DENSITY DATA

Date: 16 June 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
1627	5	25.805	
	10	25.845	
	15	25.934	
	20	26.160	
	30	26.299	
	40	26.307	
	50	26.356	
	75	26.465	
	100	26.504	
	125	26.596	
	150	26.543	
	175	26.597	
	200	26.651	
	225	26.666	
1811	5	25.751	---
	10	25.770	.48
	15	25.805	.84
	20	25.968	2.50
	30	26.235	.97
	40	26.331	.56
	50	26.372	.25
	75	26.403	.21
	100	26.481	.18
	125	26.496	.08
	150	26.520	.14
	175	26.567	.18
	200	26.613	.20
	225	26.666	---

[illegible]

TABLE VIIIa (Cont'd) - DENSITY DATA

Date: 16 June 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
2113	5	25.732	
	10	25.770	
	15	25.842	
	20	26.039	
	30	26.168	
	40	26.347	
	50	26.356	
	75	26.403	
	100	26.434	
	125	26.450	
	150	26.458	
	175	26.505	
	200	26.551	
	225	26.590	
2317	5	25.755	---
	10	25.811	1.07
	15	26.059	.98
	20	26.107	.33
	30	26.070	1.00
	40	26.340	.74
	50	26.387	.29
	75	26.426	.14
	100	26.458	.17
	125	26.512	.11
	150	26.512	.11
	175	26.567	.18
	200	26.605	.14
	225	26.636	---

TABLE VIIIb - DENSITY DATA

Date: 17 June 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
0226	5	25.755	
	10	25.851	
	15	25.975	
	20	26.024	
	30	26.259	
	40	26.332	
	50	26.356	
	75	26.419	
	100	26.465	
	125	26.535	
	150	26.574	
	175	26.574	
	200	26.594	
	225	26.621	
0424	5	25.755	
	10	25.889	
	15	26.064	
	20	26.093	
	30	26.292	
	40	26.364	
	50	26.356	
	75	26.434	
	100	26.496	
	125	26.535	
	150	26.574	
	175	26.589	
	200	26.612	
	225	26.651	

TABLE VIIIb (Cont'd) - DENSITY DATA

Date: 17 July 1971

TIME	DEPTH (METERS)	density (σ_T)	GRADIENT (σ_T/100m)
0548	5	25.850	---
	10	25.944	2.11
	15	26.064	1.84
	20	26.161	1.75
	30	26.340	.61
	40	26.364	.08
	50	26.356	.12
	75	26.434	.24
	100	26.481	.20
	125	26.535	.15
	150	26.559	.11
	175	26.589	.08
	200	26.597	.15
	225	26.666	---
0731	5	25.947	
	10	26.027	
	15	26.132	
	20	26.217	
	30	26.308	
	40	26.356	
	50	26.372	
	75	26.419	
	100	26.481	
	125	26.551	
	150	26.598	
	175	26.613	
	200	26.605	
	225	26.642	

TABLE VIIIb (Cont'd) - DENSITY DATA

Date: 17 July 1971

TIME	DEPTH (METERS)	DENSITY (σ_T)	GRADIENT (σ_T/100m)
0959	5	25.873	
	10	25.918	
	15	26.009	
	20	26.062	
	30	26.209	
	40	26.292	
	50	26.356	
	75	26.403	
	100	26.481	
	125	26.551	
	150	26.581	
	175	26.582	
	200	26.610	
	225	26.605	

APPENDIX B

DATE	TIME (PDT)	WIND (degs/kts)	SWELL (degs/ft)	SEA (degs/ft)	BAROMETER (in Hg)	SKY*	STATION
9-11-69	0255	VAR/0-2	270/3	--	29.85	Clear	Baker (B9)
9-11-69	0500	VAR/0-2	270/3	--	29.84	Clear	Baker (B10)
12-11-69	2145	000/8	300/2	--	30.10	Clear	Baker (K9)
12-11-69	2300	000/8	300/2	--	30.10	Clear	Baker (K10)
30-4-70	1900	305/15	300/8	305/3	30.07	Clear	Shepard (B10)
30-4-70	2000	315/19	310/9	315/4	30.07	Clear	Shepard (B11)
4-5-70	1200	315/13	315/4	315/2	30.02	10/1000	Shepard (K9)
4-5-70	1330	315/14	315/4	315/2	30.00	8/4000	Shepard (K10)
2-11-70	0723	VAR	280/2	Ripples	30.02	10/FOG	Soluri (K10)
2-11-70	0845	VAR	280/2	Ripples	30.02	10/FOG	Soluri (K9)
5-11-70	0855	190/20	180/5	190/3	30.00	10/1000	Soluri (B11)
5-11-70	1000	180/22	180/3	180/3	30.05	10/1000	Soluri (K10)
16-6-71	1200	305/16	300/8	305/4	29.83	Clear	Crews

Table IX. WEATHER SUMMARY

*Cloud Cover in 10ths/ceiling in ft.

APPENDIX C

1. Monterey Bay Stations:

DATE	INVESTIGATOR	STATION	SST (°C)	THERMOCLINE DEPTH (METERS)	TRANSMISSION PROFILE (m)
June 71	Crews	A	12	10-30	R.T. (0- 12) R.C. (12 - 30) C. (30 - 250)
August 69	Yeske & Waer	DELTA	13.7	10-12	R.T. (0- 15) C (15-100)
May 69	Labyak	D7,D8	11.1	25	R.C. (0-100)
April 70	Shepard	B10,B11	10.0	15	R.T. (0, 20) R.C. (20- 65) C. (65-100)
September 69	Baker	B10,B11	14.6	ISOTHERMAL	C. (0-100)
November 70	Soluri	B10,B11	13.3	65	C. (0-100)

Table X. Water Characteristics Summary

R.T.-Relatively Turbid

R.C.-Relatively Clear

C. -Clear

2. Point Montara Stations:

DATE	INVESTIGATOR	STATION	SST (°C)	THERMOCLINE DEPTH (METERS)	TRANSMISSION PROFILE (m)
May 69	Labyak	N10	10.7	15	R.T. (0- 18)
		N11	11.4		C. (18-100)
April 70	Shepard	K9	11.9	20	C. (0-100)
		K10	12.3	14	
September 69	Baker	K9,K10	14.5	20	R.C. (0- 20)
					C. (20- 40)
					R.C. (40-100)
November 70	Soluri	K9	12.9		R.C. (0- 15)
				40	C. (15-100)
		K10	13.5		C. (0-100)

Table X. (Cont'd) Water Characteristics Summary

R.T. - Relatively Turbid

R.C. - Relatively Clear

C. - Clear

APPENDIX D

Figure 51a, XBT Traces, 16 June 1971

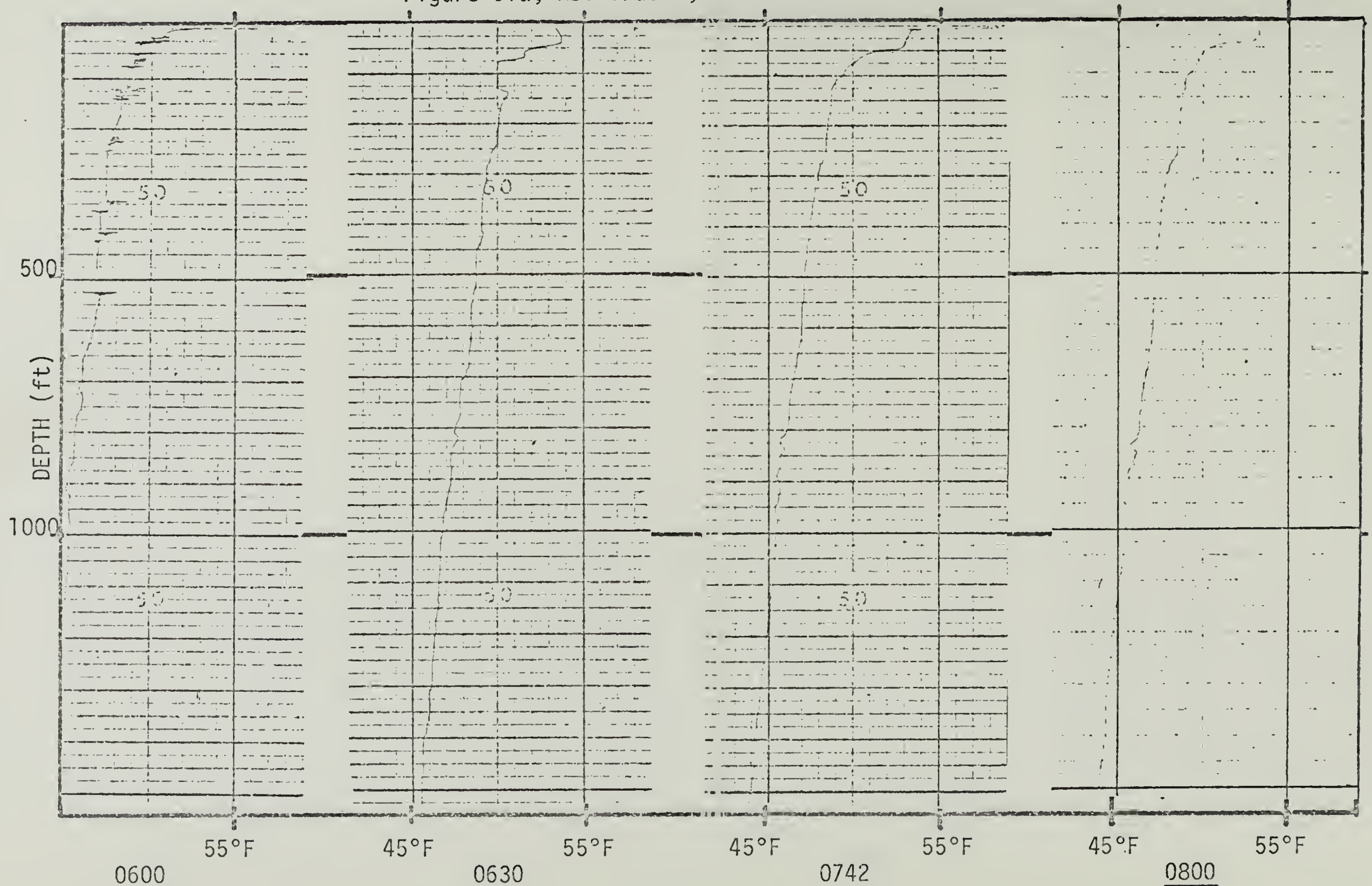


Figure 51a - XBT Traces, 16 June 1971

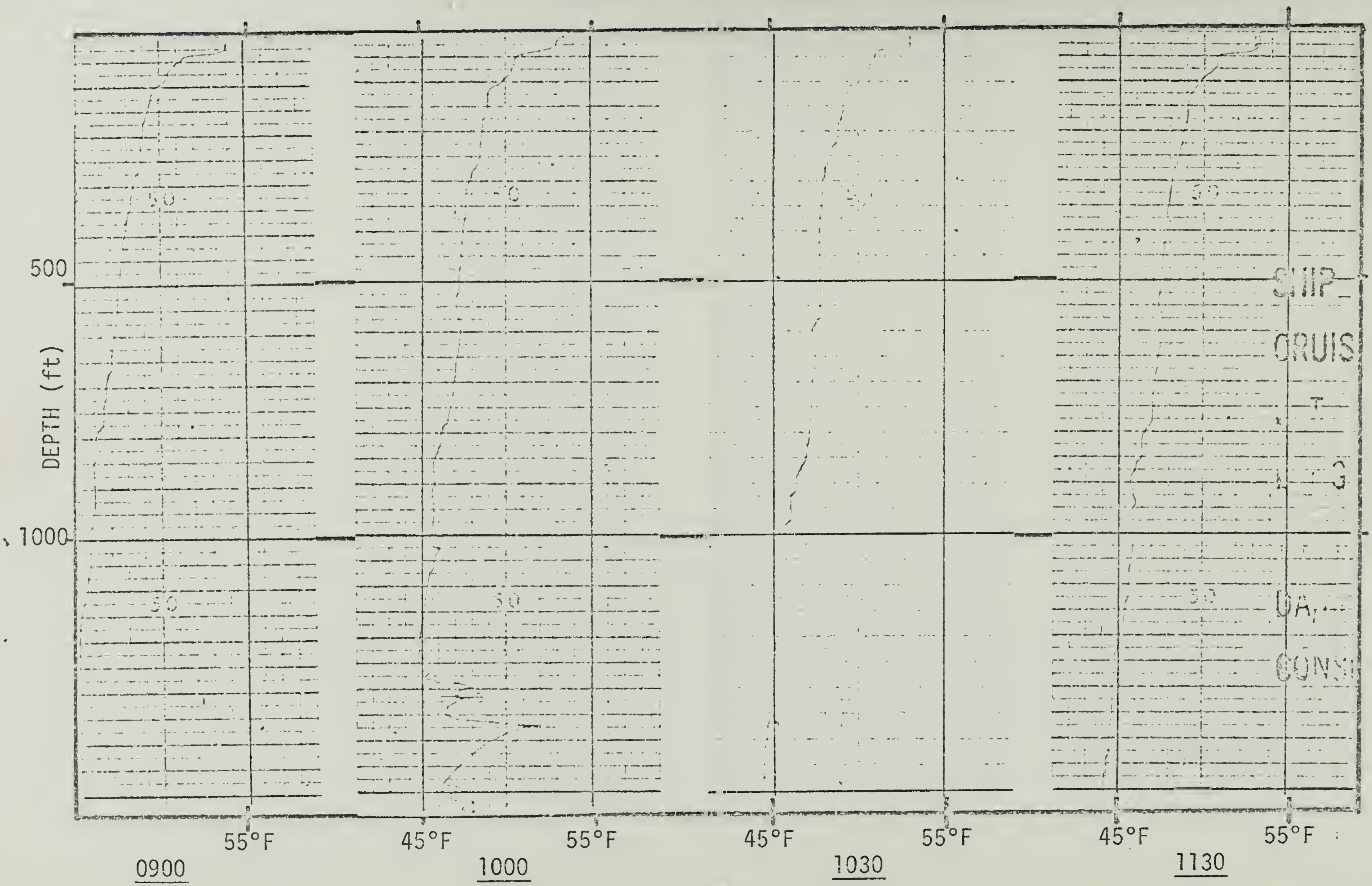


Figure 51a. XBT Traces, 16 June 1971

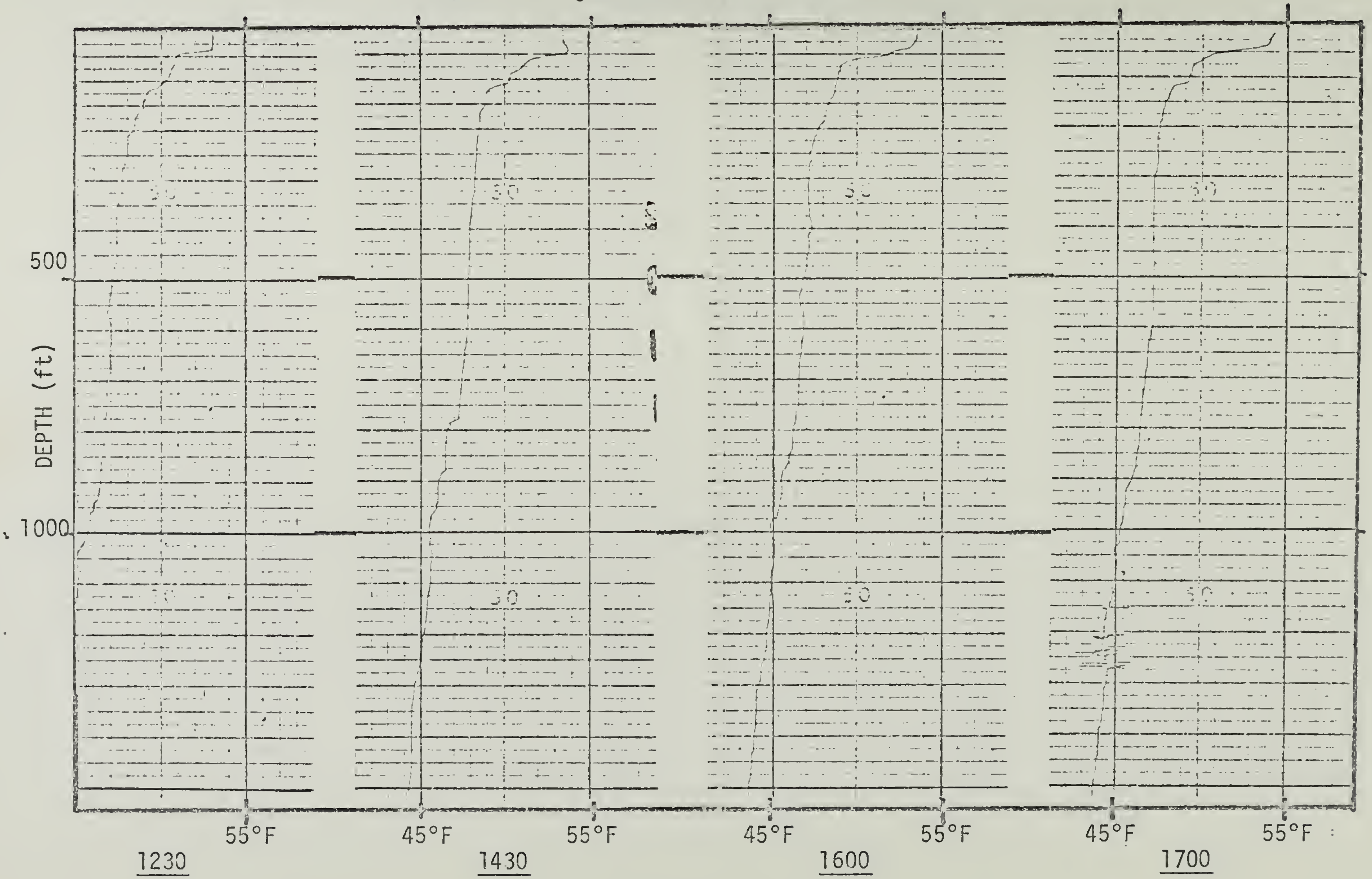


Figure 51a. XBT Traces, 16 June 1971

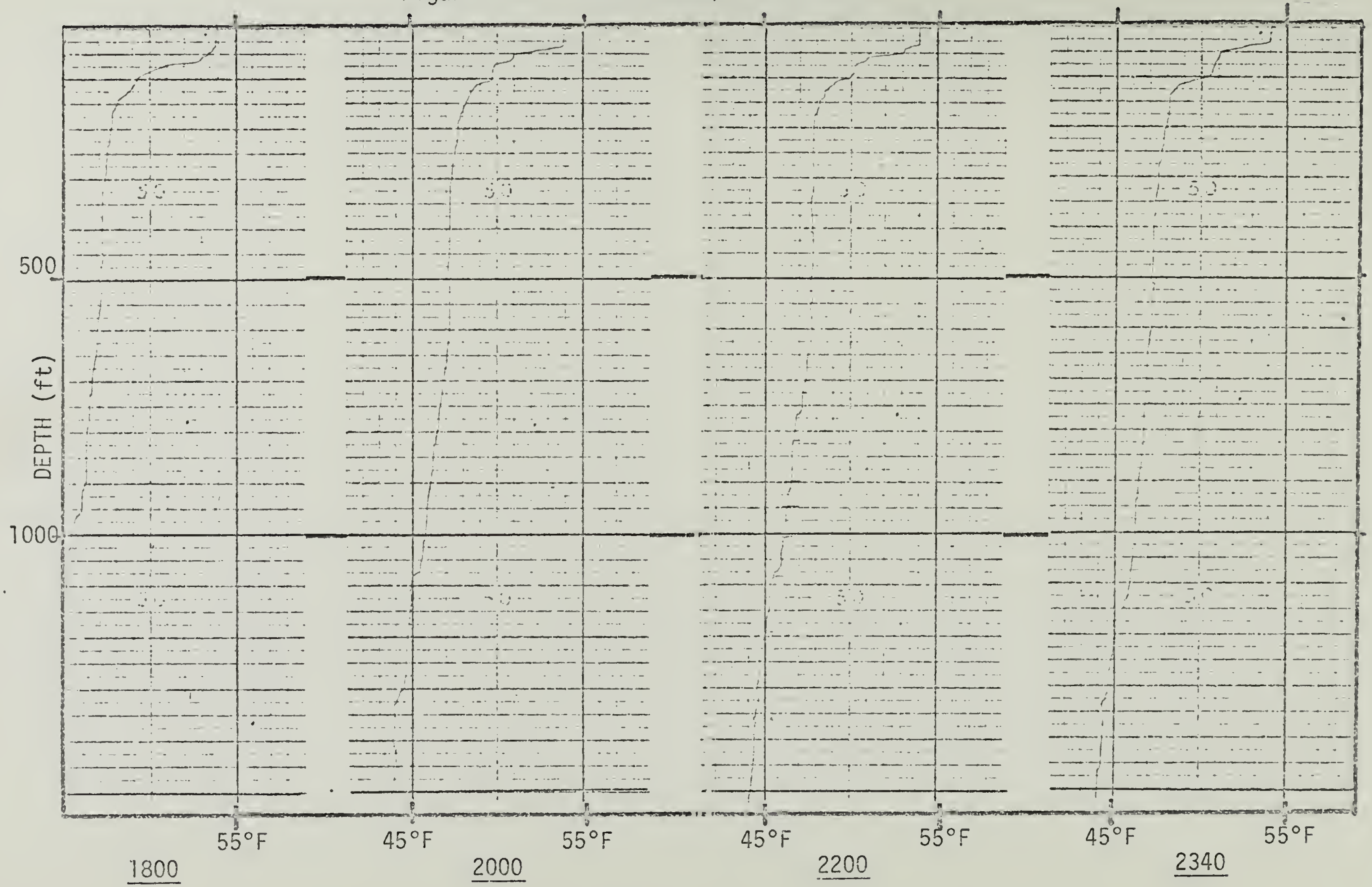


Figure 51b - XBT Traces, 17 June 1971

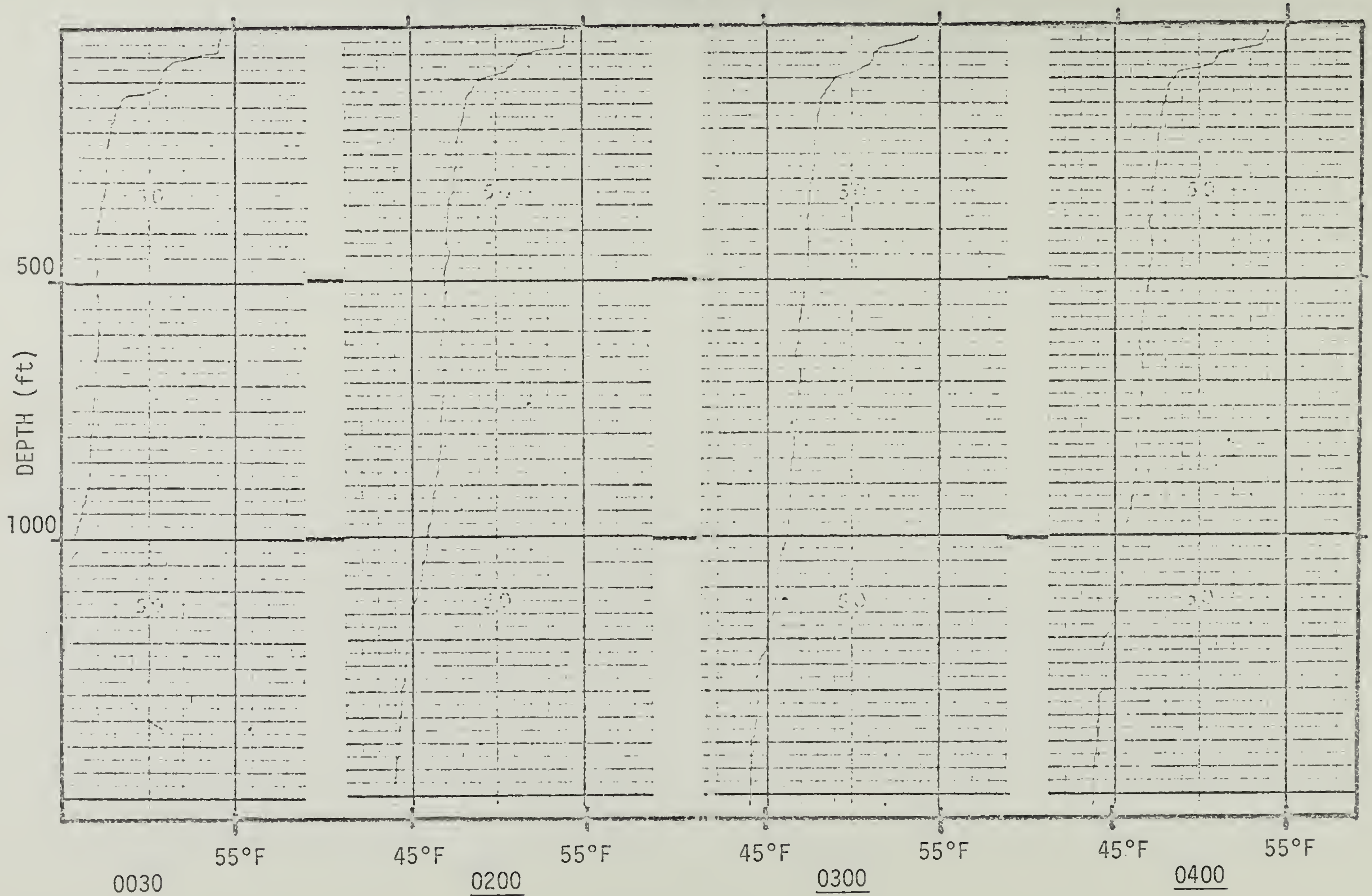
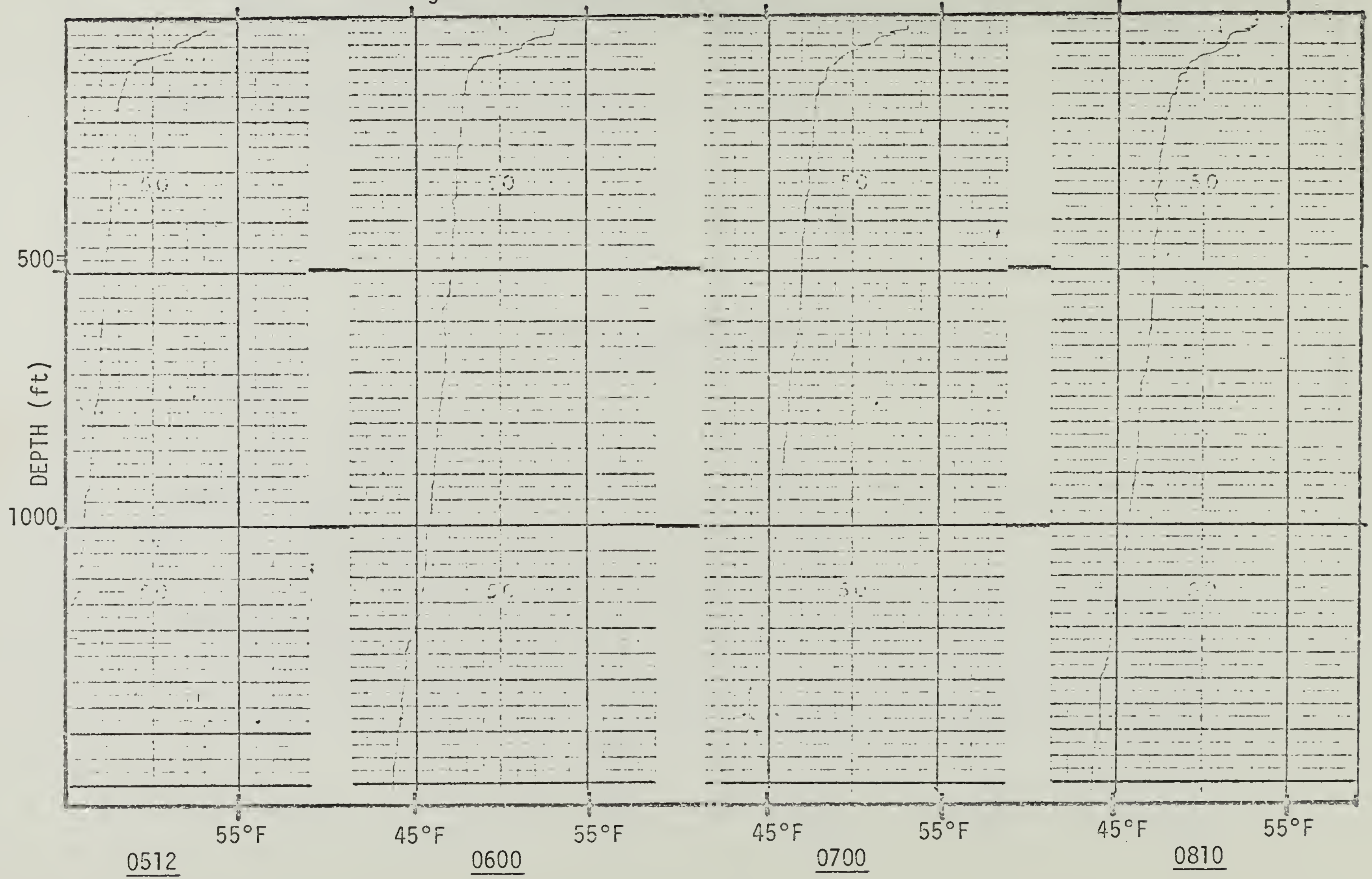


Figure 51b. XBT Traces, 17 June 1971



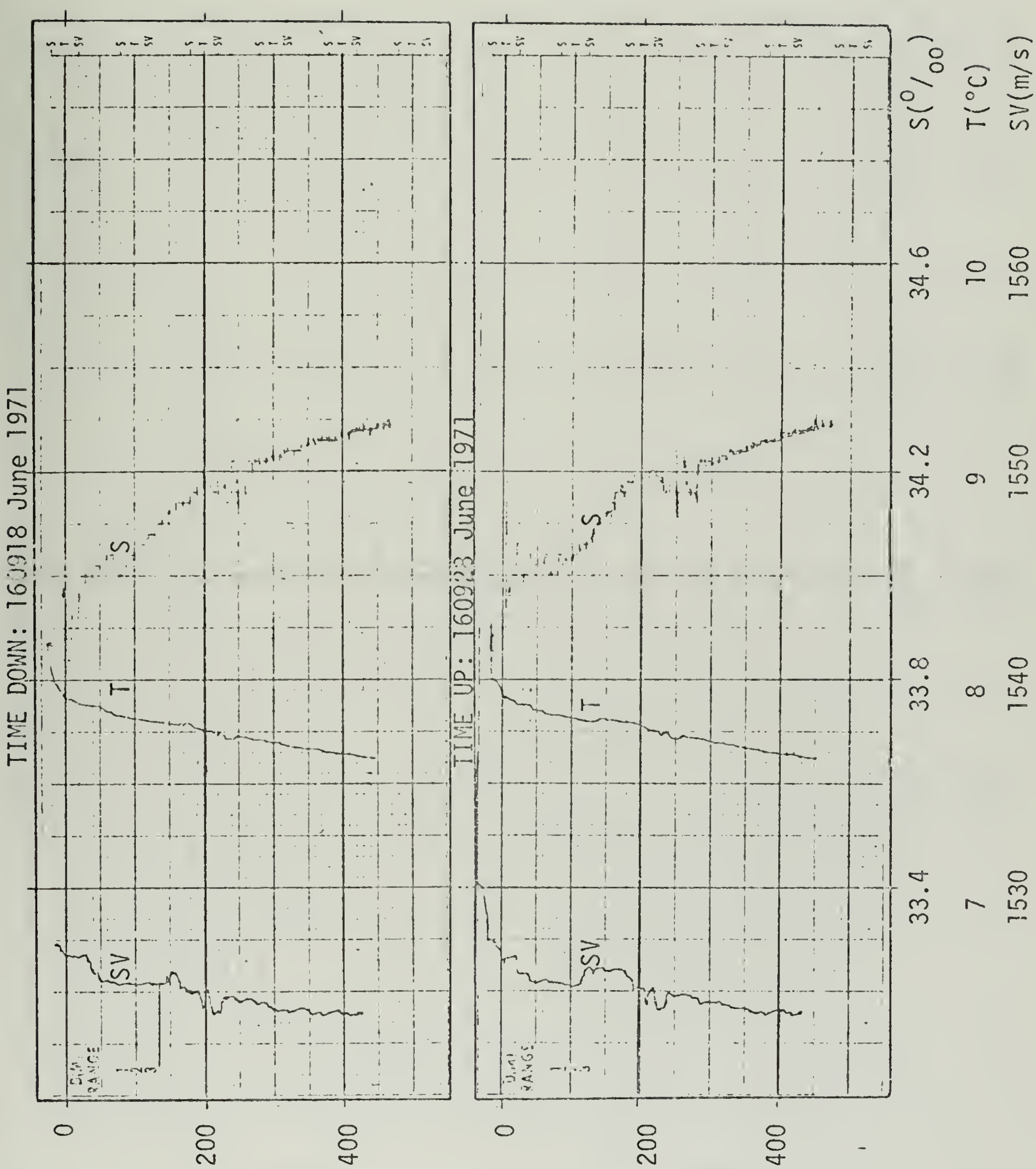


Figure 52a. S/T/D/SV Traces.

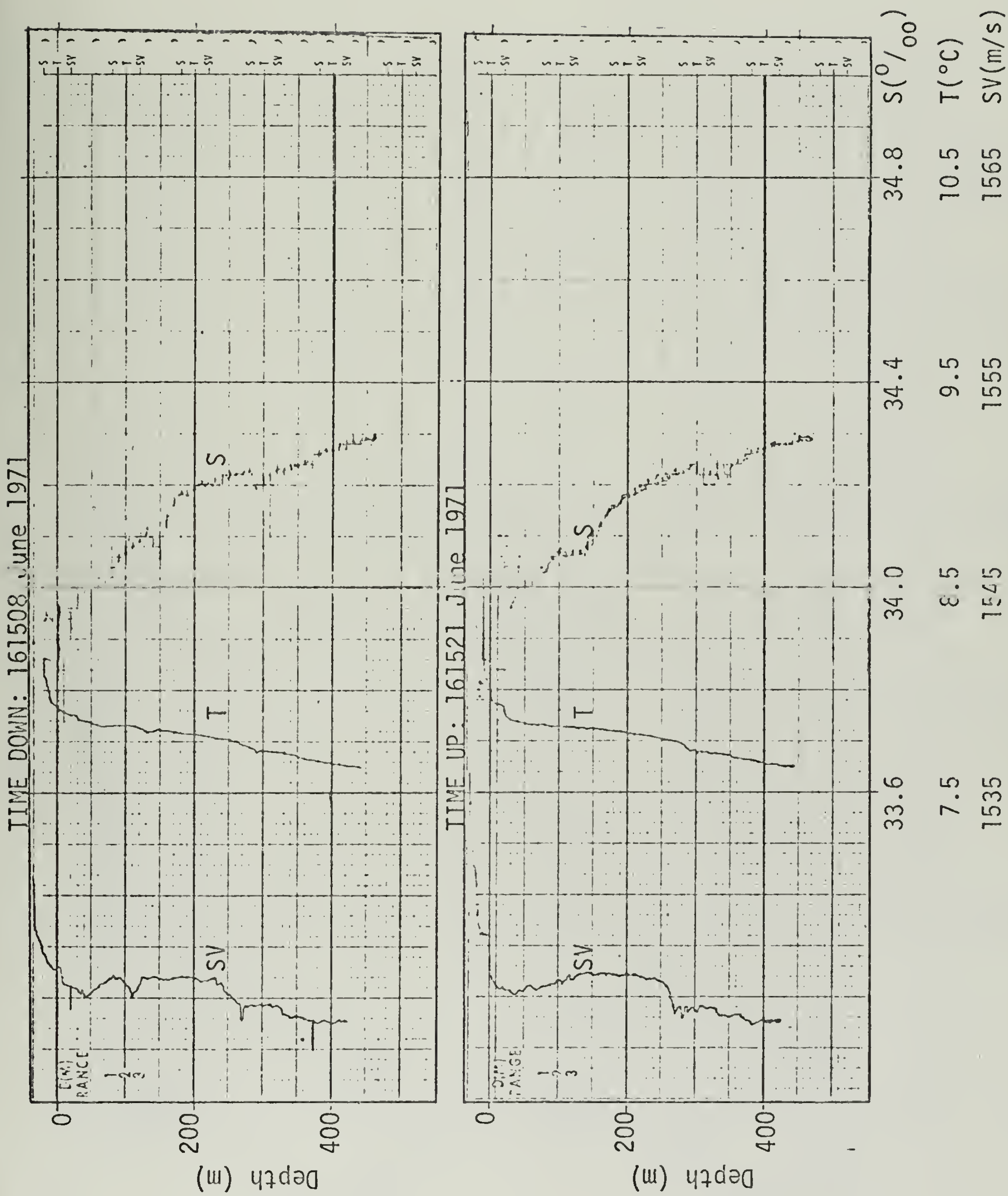


Figure 52b. S/T/D/SV Traces

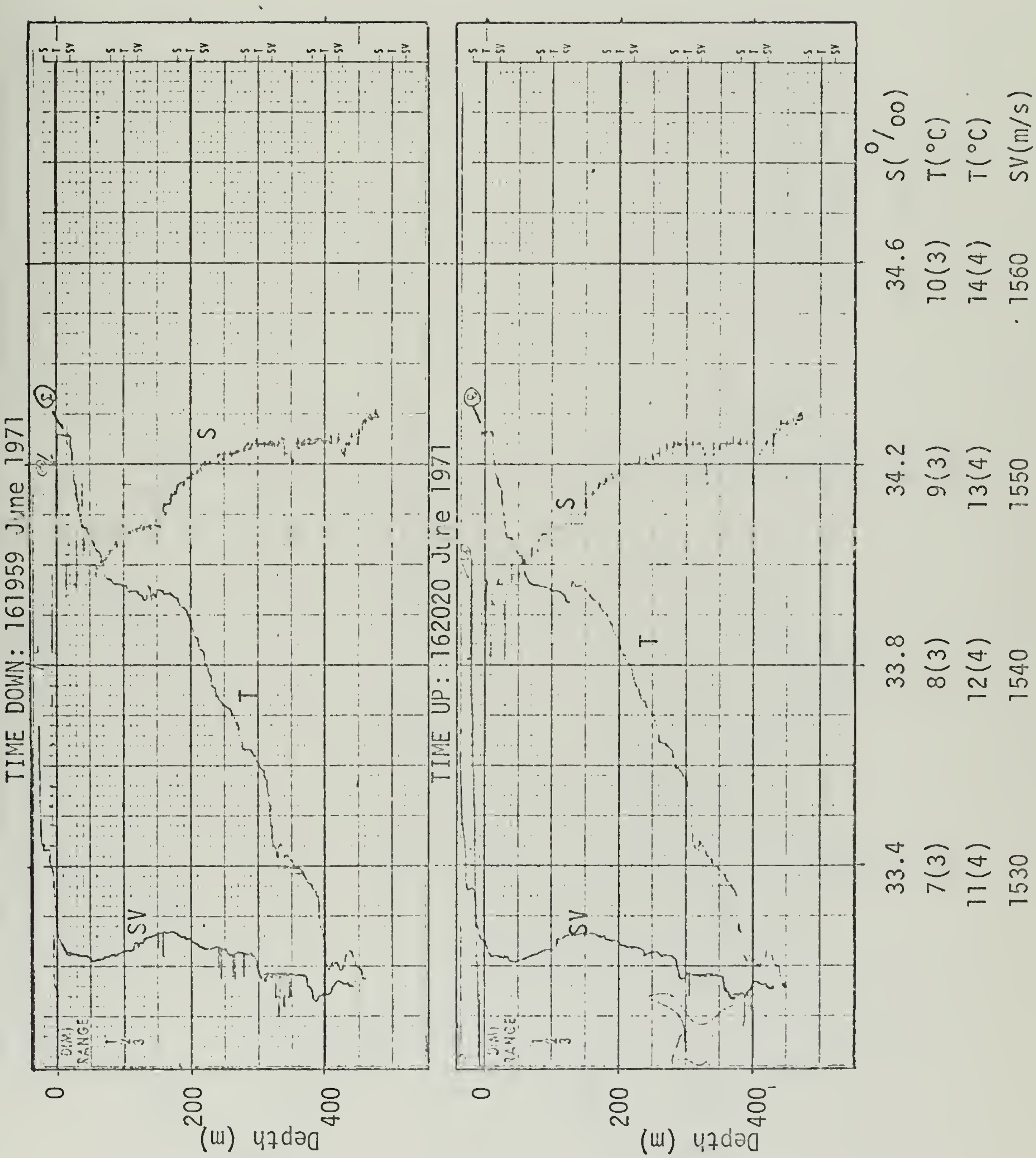


Figure 52c. S/T/D/SV Traces.

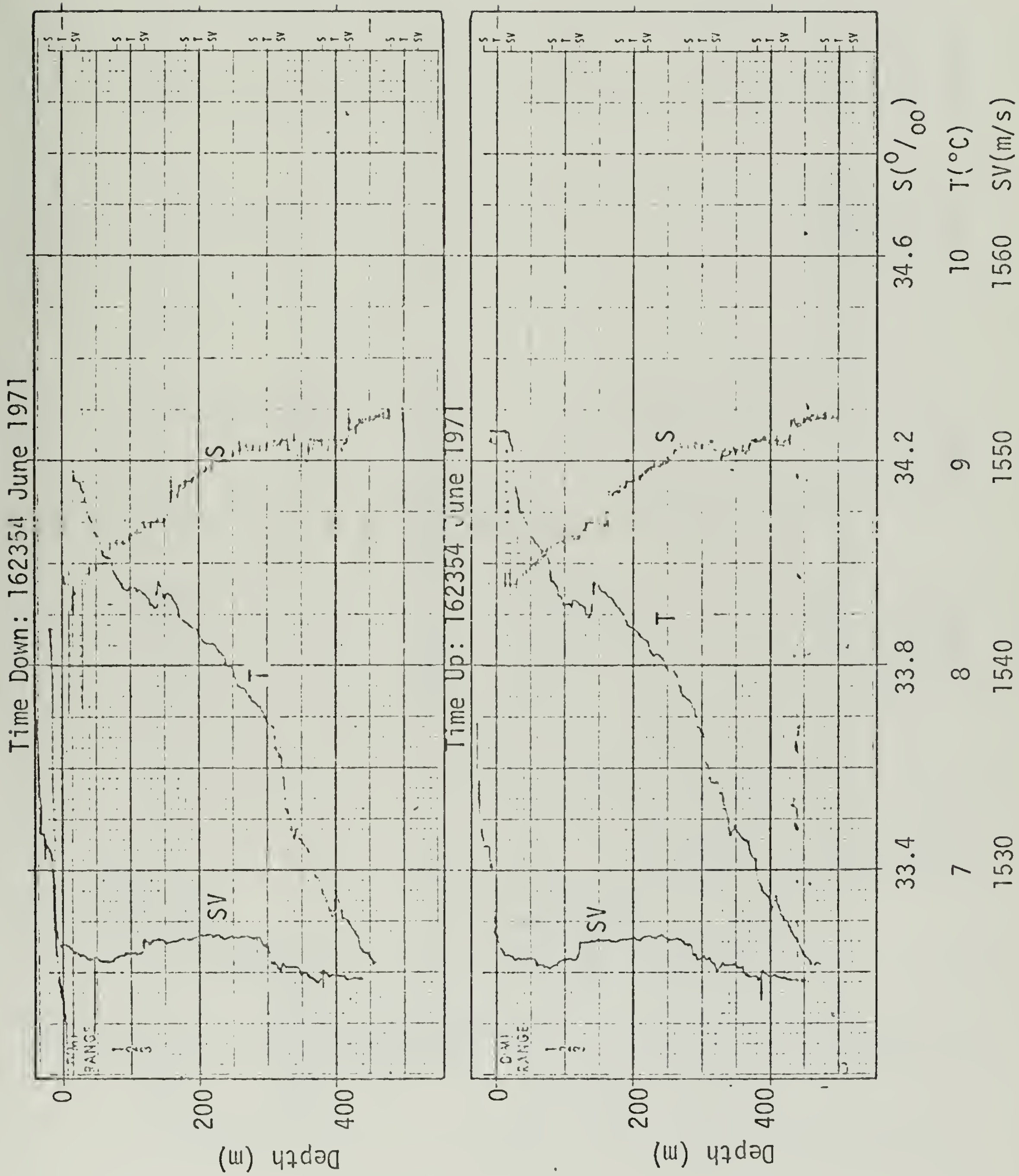


Figure 52 d. S/T/D/SV Traces.

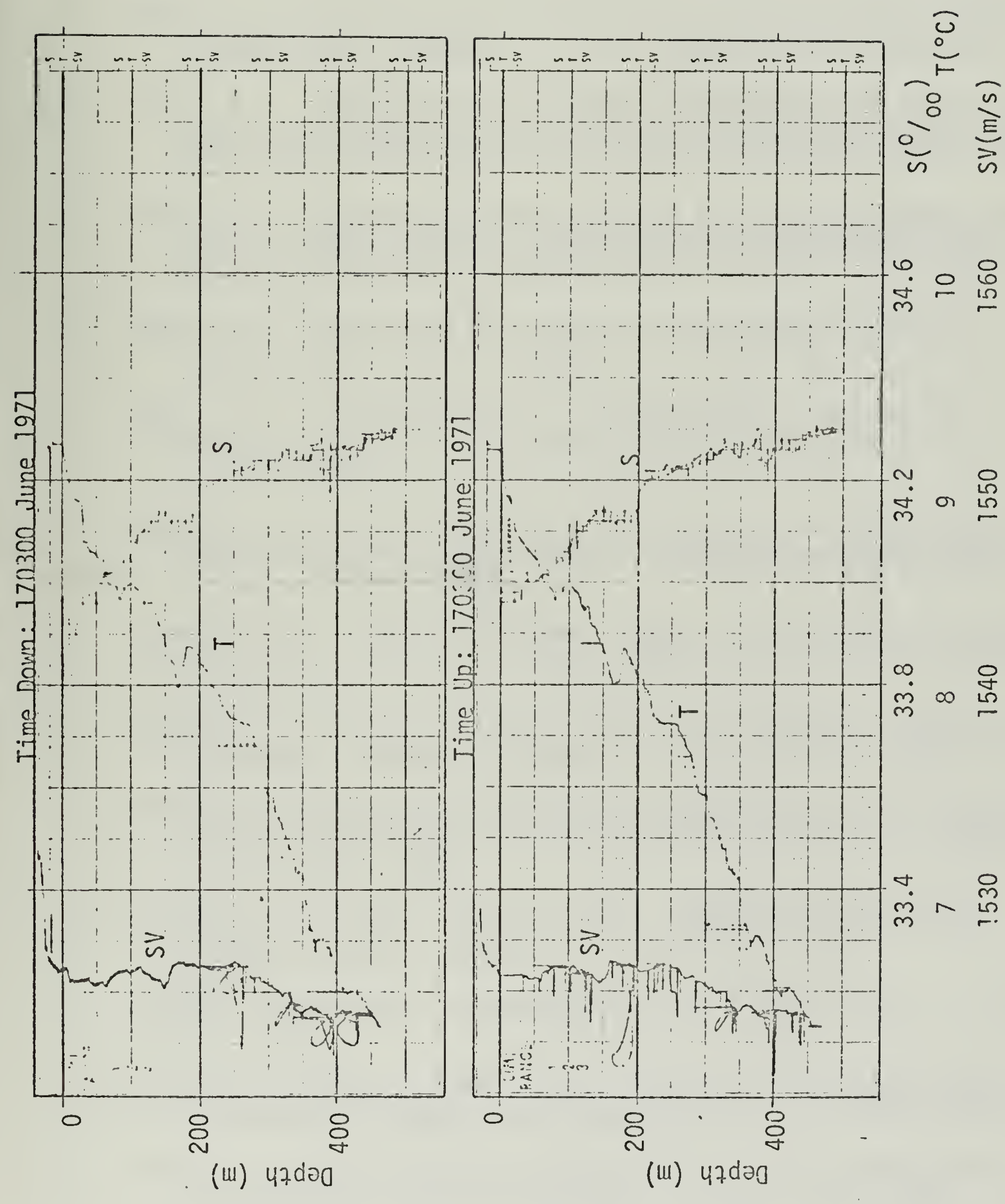


Figure 52e. S/T/D/SV Traces.

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13. ABSTRACT

A single ocean station was occupied for 27 hours during the Upwelling Period in Monterey Bay, California, to study light attenuation and its relation to other standard oceanographic parameters. Comparisons were made with earlier local studies.

It was found that the vertical distributions of the oceanographic parameters studied are dependent on both the seasonal conditions and geographical location.

The largest concentration of suspended particles was found in the upper 10-15 m of the water column where most of the light attenuation occurred. The largest attenuation gradient was found in the pycnocline. A linear relation was suggested between the attenuation coefficient and the cumulative projected cross-sectional area of the particles.

Apparent relations were found between light attenuation and temperature, salinity, density, and oxygen and phosphate concentrations.

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